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INSTITUTE FOR DEFENSE ANALYSES

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June 1999

IDA Paper P-3409

Log: H 98-001713

This work was conducted under contract DASW01 98 C 0067, Task AH-5-490, for the Office of the Director, Industrial Capabilities and Assessments, Office of the Deputy Under Secretary of Defense for Industrial Affairs. The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

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Preface

This paper was prepared for the Office of the Director, Industrial Capabilities and Assessments, Office of the Deputy Under Secretary of Defense for Industrial Affairs, under the task order Integrated Diagnostics and Improved Affordability for Weapon Support Systems. It addresses a task objective, to develop strategies and requirements for the technical content of product data packages needed to maintain and upgrade weapon systems after the initial production phase.

The following Institute for Defense Analyses research staff members were reviewers of this document: Dr. Richard J. Ivanetich, LTG Peter Kind, USA (Ret.), Mr. Michael S. Nash, and Dr. William R. Simpson.

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Executive Summary

Introduction

Historically, the Department of Defense (DoD) has attempted to acquire large amounts of technical data relatively early in the weapon system acquisition process. The results were not always favorable (e.g., some data were never used, costs were needlessly increased because of unique data formats).

Recent DoD data strategies were intended to reduce these effects by making technical data, generated incidental to product development and production, accessible only when needed and then in the data's native formats. However, changes in product design technologies, as well as changes in DoD acquisition policies and practices, are affecting the acquisition and support of systems. These changes may affect future technical data needs and DoD's ability to meet these needs.

The Institute for Defense Analyses was tasked by the Director, Industrial Capabilities and Assessments, Office of the Deputy Under Secretary of Defense for Industrial Affairs, to assess if technical data for mechanical systems and parts will be adequate in this new era to meet defense procurement and support needs during a system's post-production lifetime.

Approach

Initially, we began assessing current and future DoD technical data requirements for mechanical-based post-production products acquired by DoD. During the course of the study, this task was expanded to include technical data requirements from the perspectives of both the prime contractor and subcontractor. To address this broader subject area, we identified three objectives:

- **Objective 1.** Identify changes to mechanical-based technical data content, form, and media that will result from technical advances and recent acquisition reform initiatives.
- **Objective 2.** Assess if future mechanical-based technical data will be adequate for DoD or contractor competitive procurement.
- **Objective 3.** Identify the mechanical-based technical data that DoD will need to support the functions of buying, modifying, and maintaining post-production products.

We collected information from three principal sources: literature and on-line data searches; interviews with defense systems acquisition, support, and logistics managers; and CAx developers, suppliers, and users. (The term "CAx" refers to computer-aided tools for design, manufacturing, engineering, etc.)

From these sources, we developed our own definition of "technical data packages" (TDPs) for the purposes of this study:

> Sets of technical information, either currently collected or capable of being accessed and collected, that provide a technical description of items adequate for the intended use of that data.

In the early stages of analysis, we were able to postulate the following vision:

> System integrators and major subsystem primes are effectively becoming sole-source suppliers and program representatives (under contract to defense programs) for providing long-term sources of spare parts, maintenance, repair, and design configuration control of defense systems.

These new practices are derived from multiple factors, among them:

- Acquisition reform initiatives.
- Restructuring of defense industry.
- High priority assigned to commercial-off-the-shelf (COTS) items.
- A new defense policy giving preference to performance-based specifications.
- New policy initiatives that assign detailed design control below performance specifications to the contractors.
- Defense initiatives to minimize the amount of product data acquired.
- New objectives permitting contractors to repair or update design configuration to performance specifications as a normal course of business.

This vision was the basis for expanding the task to include contractor purchasing decisions, that is, the adequacy of technical data for a contractor to use in procurement—specifically competitive procurement—when acting in support of defense products or systems.

Conclusions

To assist the reader, we have grouped our conclusions by their relevant task objectives.

Objective 1. Identify changes to mechanical-based technical data content, form, and media that will result from technical advances and recent acquisition reform initiatives.

Conclusion 1. The three-dimensional solid models produced by advanced CAx technology tools are improving technical data development, modification, descriptive capabilities, and long-term digitally stored data management and retrieval. Improved capabilities include shorter design times, enhanced design accuracy and quality, and new integrated design verification tools. Technology advances are improving data-exchange capabilities between CAx systems. New COTS data management and storage capabilities are permitting the growth of common data storage facilities. Technology advances are eliminating the need to duplicate and manage data at multiple (redundant) contractor and defense facilities, making data more accessible to users.

Conclusion 2. A very strong relationship exists between three types of data populating TDPs and specific post-production acquisition and support strategies for which the data are needed.

DODI 5000.2-R, Mandatory Procedures for MDPAs and MAIS Acquisition Programs, stipulates that program managers

> shall develop and document an acquisition strategy that shall serve as the roadmap for program execution from program initiation through post-production support.

The program and logistics managers interviewed indicated acquisition reform initiatives are being widely adopted and have stimulated the increased reliance on digital data in the contractors' own formats and the preference for on-line access of data through contractor information services rather than data delivery. The data content, whether delivered to DoD or retained in contractor's repositories, tended to correlate closely with the specific acquisition and support strategy for individual items identified in the mandatory acquisition plans for each program.

Objective 2. Assess if future mechanical-based technical data will be adequate for DoD or contractor competitive procurement.

Conclusion 3. Emerging acquisition strategies will likely reduce the overall adequacy of future TDPs for competitive re-procurement of products and services by DoD.

We identified four contributing factors that may reduce post-production competition between current and alternative competent manufacturers:

- Overall percentage of data with limited rights is likely to increase.
- Long-term contractor representatives (sole-source) arrangements are being planned.
- Acquisition strategies based on performance will tend to assign design and configuration control responsibilities to original contractors.
- Additional costs are associated with developing performance specifications and their requisite quality assurance provisions, and with conducting compatibility testing for assembly levels below existing performance specifications.

This situation does not preclude competitive procurement of post-production products and services by contractor representatives of the program office. Furthermore, contractor representatives in all likelihood will have been selected as a result of competition. Consequently, the next conclusion addresses the adequacy of future TDPs under long-term contractor representatives arrangements.

Conclusion 4. For situations where contractors retain data rights or control design configurations, the relative quality and adequacy of TDPs will be as good or better than for TDPs retained by the government in the past.

Many of the data quality and accuracy improvements are independent of ownership and control, and are driven by CAx technology advances. In general, TDPs should be adequate for competition by sole-source program representatives, especially in situations where contractor representatives own data rights or control design configurations.

Potential higher spare parts costs (attributed to pass-through charges or non-competitive purchases) may be offset by the elimination of duplicative government functions of data storage and management, spare-parts item management functions, and evolutionary product improvements through agent-managed performance-based acquisitions.

Objective 3. Identify the mechanical-based technical data that DoD will need to support the functions of buying, modifying, and maintaining post-production products.

Conclusion 5. Technical data are adequate if they meet requirements of the specific intended post-production use. We characterized this use by three distinct situations:

- Competitive or non-competitive procurement of replacement part(s) or parts support.
- Design configuration control of assembly by DoD or contractor(s).
- Maintenance or support of assembly performed by DoD or contractor(s).

Based on the composite of our observations showing similar "best practices" being applied to common situations, we developed the guidelines in Table ES–1 on page ES–5 to identify what data are needed to be adequate for meeting each of the case situations. Because there are three independent situations, each with two alternatives, there are eight unique lifecycle strategy conditions that may occur at each level of product assembly (e.g., part, assembly, subsystem).

The first column (labeled "#") is only used for convenience's sake, to label each of the eight unique conditions at the specific item level.

The next three columns (Competitive Procurement, Design Configuration Control, and Maintenance) identify the specific acquisition lifecycle attributes that pertain to each of the unique strategy conditions.

The fifth and last column lists possible strategies for which available data would be adequate to meet the data's intended use as constrained by the unique lifecycle strategy

conditions that may occur at each level of assembly.

These unique lifecycle strategies are conditions that depend on how replacement units at each level of assembly are procured, controlled, and maintained.

Recommendations

Recommendation 1. DoD should adopt mechanisms to systematically assess near- and long-term technical data needs, and identify optimum lifecycle strategies to accommodate changing conditions.

We recommend that DoD develop and provide guidelines to program offices for identifying post-production technical data requirements to assure adequacy for specific maintenance strategies planned or implemented at each level of product assembly. Most of the individuals interviewed said they wished they had had recommended guidelines and strategies when they were tailoring TDP requirements.

While it is unlikely that a single strategy or guideline will address all potential technical data requirements that may occur, we believe that guidelines of this nature should be developed. These guidelines should be given to acquisition strategy planners as one of several options for assessing technical data.

Recommendation 2. DoD should evaluate alternative technical data guidelines applicable to other than mechanical-based product categories.

While not the initial focus of this study, other product categories such as engines, hydraulics, electronics, etc., may be amenable to the suggested guidelines in Table ES-1 on the next page or some other very similar guidelines. We recommend that an appropriate future course of action in developing technical data guidelines should include an integrated product team specifically chartered to investigate technical data strategy guidelines for program managers to use in evaluating their options.

Table ES-1. Strategy Guidelines for Tailoring Technical Data Requirements to Situation-Dependent Needs

Unique Situations at Each Product Assembly (Eight Potential Situations for Each Part, Assembly, etc.)				Strategies for Assuring Technical Data Will Be Adequate in Each Situation
#	Competitive Procurement	Design Configuration Control	Maintenance	General Data Strategy to be Applied at Each Assembly Level
1	Yes	DoD	DoD	• Detailed drawings with data rights *or* • Performance specs[a] plus logistics form, fit, function, interface (F^3I) requirements[b]
2	Yes	DoD	Contractor	• Detailed drawings with data rights *or* • Performance specs
3	Yes	Contractor	DoD	• Performance specs plus logistics F^3I requirements
4	Yes	Contractor	Contractor	• Performance specs
5	No	DoD	DoD	• Drawings (not critical that all details and processes available nor that data have unlimited rights)[c]
6	No	DoD	Contractor	• Performance specs plus drawing changes[d] *or* • Drawings (not critical that all details and processes available nor that data have unlimited rights)
7	No	Contractor	DoD	• Performance specs plus logistics F^3I requirements
8	No	Contractor	Contractor	• Performance specs

a Performance specs are (1) form, fit, function requirements at the assembly level, and (2) interface and performance requirements allocated from the next higher level of assembly.

b Logistics F3I requirements refers to any additional performance and interface requirements associated with the logistics infrastructure when the item is used (e.g., support equipment, manuals, training).

c Implies that total design, engineering know-how, or unique manufacturing processes may be less than fully disclosed in the data, or the documentation may include limited rights data.

d The statement "plus drawing changes" implies that changes to drawings will be coordinated with DoD and approved by the responsible DoD agent.

1. Introduction

1.1 Purpose

Initially, the Institute for Defense Analyses (IDA) was tasked by the Director, Industrial Capabilities and Assessments, to assess whether technical data for mechanical systems developed in conjunction with existing and planned defense systems will be adequate to meet post-production[1] defense procurement and support needs in the new era of acquisition reform and rapid technology advances. The initial objective of the study was expanded during the course of the study to three objectives. This allowed the IDA study team to include technical data requirements from the perspectives of both the prime contractors and sub-contractors.

- **Objective 1.** Identify changes to mechanical-based technical data content, form, and media that will result from technical advances and recent acquisition reform initiatives.
- **Objective 2.** Assess if future mechanical-based technical data will be adequate for DoD or contractor competitive procurement.
- **Objective 3.** Identify the mechanical-based technical data that DoD will need to support the functions of buying, modifying, and maintaining post-production products.

The focus of the study is the technical data packages (TDPs) used after initial production and throughout the rest of the system lifecycle (post-production).

1.2 Background

Historically, the Department of Defense (DoD) has attempted to acquire large amounts of technical data relatively early in the weapon system acquisition process. Intended uses of this data included supporting the following:

- Systems configuration control and management.

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1 Post-production represents the remaining product lifetime after initial production is completed.

- Competitive acquisition of spare and replacement parts.
- Future competitive acquisitions or modifications of weapons system products.
- The competitive acquisition of product support functions.

However, the consequences of the traditional technical data strategy were not always favorable:

- Contractors objected to having to provide a means for competitive procurement, maintenance, or spares support on what they viewed as proprietary information.
- Frequently, portions of the technical data were never needed nor used.
- Technical data costs were needlessly increased because of specialized DoD data requirements or unique DoD formats.
- Duplicate data storage, retrieval, configuration management, and distribution functions frequently existed at contractors and at multiple defense locations.

New data strategies are intended to reduce the unfavorable effects of these consequences by making technical data, generated incidental to product development and production, accessible only when (or if) needed and then in the data's native formats. This new data strategy is part of a Revolution in Business Affairs[2] (RBA) that dominates a new era of DoD system acquisition and support. While the full effects of the RBA are not yet fully understood by DoD, we can characterize this new era by the eight critical drivers described briefly in the following subsections.

Defense budget decline. The defense budget, while now relatively stable, has undergone a significant decline since the mid-1980s. In his 1997 *Annual Report to the President and Congress,* Secretary of Defense Cohen stated the following:

> The DoD budget authority requested for FY 1998 is, in real terms, about 40 percent below its level in FY 1985.[3]

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[2] "The RBA includes reducing overhead and streamlining infrastructure; taking maximum advantage of acquisition reform; outsourcing and privatizing a wide range of support activities when the necessary competitive conditions exist; leveraging commercial technology, dual-use technology, and open systems; reducing unneeded standards and specifications; utilizing integrated process and product development; and increasing cooperative development with allies" [Sanders 1997].

[3] Authors' note: "real terms" meaning inflation-adjusted defense budget authority.

As reported by a recent Defense Science Board, the defense procurement budget experienced a major portion of this decline with reductions of over 65% since peaking in the mid-1980s [DSB 1997, p. 7].

Defense industry consolidation. Recently, the defense industry has undergone dramatic consolidation, with over a dozen acquisitions of large-sized firms worth over one-billion dollars and numerous smaller acquisitions involving medium size firms. The number of firms with the top two-thirds defense sales is down 46% since 1987 [DSB 1997, p. 20].

Strategy to out-source support. In the same annual report, Secretary Cohen also acknowledged that

> [t]he Department continues to work hard to identify which of its functions might be transferred to the private sector without adversely affecting operations. The goal of this outsourcing is to increase efficiency, save money, and enhance efficiency.

Preferred use of performance specifications.4 In his 1994 memorandum, *Specifications & Standards—A New Way of Doing Business*, then-Secretary of Defense Perry established a new defense policy that called for greater use of

> performance and commercial specifications and standards in lieu of military specifications and standards, unless no practical alternative exists to meet the user's needs.

These policy changes have been promulgated in current DoD directives, instructions, and guides.

Distributed configuration control. Secretary Perry's 1994 policy memorandum also stated

> To the extent practicable, the Government should maintain configuration control of the functional and performance requirements only, giving contractors responsibility for the detailed design.

This policy guidance has been promulgated in current DoD directives, instructions, and guides.

Buying less data. DoD's Continuous Acquisition and Lifecycle Support (CALS) program called for the deployment of an Integrated Data Environment (IDE) concept in 1994. Under this concept, the contractor retains data in the contractor's preferred IDE data formats, permitting DoD to obtain data if and only if needed [IDE 96]. Variations of this initiative are now being applied across the Services, with near-term benefits of reduced initial data costs for engineering documentation and technical data packages.

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4 Performance specifications are also referred to as *form, fit, function, interface (F3I) specifications.*

Emphasis on commercial items and competition. Legislative actions have increased emphasis on the use of competition and assigned preference to the use of commercial-off-the-shelf (COTS) items. These actions include the Competition In Contracting Act (1984), Federal Acquisition Streamlining Act (1994), and Federal Acquisition Reform Act (1995).

Evolution of computer-assisted design technology. The computer revolution of the past three decades has played a dominant role in advancing automated and assisted design, manufacturing, and engineering capabilities specifically related to CAx[5] technologies.

1.3 Scope and Approach

IDA was asked by the study sponsor to specifically focus on mechanical sub-systems, and to assess how technical data content, form, and media for these sub-systems are changing as the result of technology advances and the affects of RBA on defense systems acquisition and support. This focus on mechanical sub-system was endorsed early during our study efforts by the F/A-18 Assistant Program Manager for Logistics.

> A substantial portion of my time is consumed with immediate issues related to rapidly changing electronics, component obsolescence, and diminishing manufacturing sources. Consequently, data on electronic systems tends to be available, and in a constant state of update or revision; while mechanical-based designs tend to be more stable and as such may be more prone to long-term post-production technical data package difficulties [Howard 1997].

We conducted an initial search for information using the following sources:

- **Open literature and Internet sources.** Sources included DoD and service directives, policies, acquisition reform initiatives, Federal Acquisition Regulations and their Defense Supplement, U.S. laws, and defense and industry standards.

- **Defense systems acquisition, support, and logistics managers.** Interviews were conducted with representatives of Naval Supply Systems Command, Naval Inventory Control Point, Air Force Logistics Centers, Defense Logistics Agency, F/A-18 Program Office and Logistics Team; and with LPD-17 Logistics Support Managers.

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5 The term "CAx" refers to a variety of computer-aided or assisted design and manufacturing functions, e.g., computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE).

- **On-site interviews.** CAx developers, suppliers, and users. Interviews were conducted with representatives of the National Institute of Standards and Technology, South Carolina Research Authority, and major CAx suppliers.

This information was used to evaluate adequacy and accessibility of technical data to meet future contractual needs of defense and contractor organizations.

While defense acquisition reform policy and initiatives are mentioned throughout this document, we did not attempt to assess their relative benefits. Given the scope of this study, we instead assessed the relative effects of these policy and initiatives on technical data and TDPs, and the future application of this data by DoD and contractors.

1.4 Organization of This Paper

Chapter 1 presents a brief overview of the history of the tasking and the background and problem this paper addresses and documents. As part of this background, we identify eight critical drivers that characterize the new DoD data strategies. We also describe our scope and approach in data collection and analysis.

Chapter 2 introduces and discusses definitions of technical data packages and provides an overview on when and how they are typically used.

Chapter 3 summarizes the results of our interviews with both the defense systems acquisition, support, and logistics managers; and with the CAx developers, suppliers, and users.

Chapter 4 contains an overarching vision reflecting a new acquisition era with greater levels of contractor representation for the lifecycle support of defense systems. This vision was the basis for the sponsor's decision to expand IDA's tasking to include analyzing contractor purchasing decisions.

Chapter 5 contains the conclusions of the IDA study team's analyses.

Chapter 6 presents recommendations that respond to the desire by many of the individuals interviewed for better defense guidance on tailoring technical data requirements.

Appendix A contains detailed background information and a technical assessment of what constitutes an adequate TDP for competitive procurement. As part of this discussion, information is provided concerning (1) major barriers to competitive procurement, and (2) the effects of new CAx technologies and new defense policies and practices.

Appendix B provides a brief summary of the Electronic Data Processing Library (eDAL) concept being implemented by the Boeing Company for the F/A-18E/F.

Appendix C contains a brief discussion of the verification requirements typically needed as a critical part of TDPs used in contractual actions.

References and a list of acronyms and abbreviations are provided at the end of this paper.

2. Technical Data Packages: An Overview

In this chapter, we identify and define terms used by government and industry. We also refine or expand certain terms for use in our study. This is to prepare the reader for our discussions in this chapter and later of how and when TDPs are used, issues and trends in DoD policies and practices, and our vision of future acquisition practices. Finally, we briefly discuss the uses of TDPs in a system's lifecycle.

2.1 IDA Definitions

2.1.1 Technical Data Package

Initially, we used a 1992 Army definition of TDPs:

> Sets of technical information, either currently collected or capable of being accessed and collected, that provide a technical description of items that are adequate for the intended use of that data. In one such intended use, TDPs serve as the technical element of a contractual business arrangement between the government and industry contractors to procure or reprocure, repair, support or redesign an item. Typically, TDPs include information concerning an item's description, requirements, verification, and packaging [TDP 1992].

However, recent effects of acquisition reform and technology advances have reduced the emphasis on the acquisition and delivery of individual packages of technical information that defines a specific item (system, subsystem, assembly, etc.). We then refined the term "technical data package" to mean

> sets of technical information—either currently collected or capable of being accessed and collected—that provide a technical description of items that are adequate for the intended use of that data.

Our definition is distinguished from the historical definitions in one single and important aspect: that information need not have been collected and delivered to a user as a specific package of data before a time when it is needed. Instead, technical information may be accessed and collected when needed from a range of locations with data in different mediums or formats. Aside from this distinction, the definition and application of technical data packages (and its acronym) are unchanged from their historical or current usage.

In further examining the details of our definition of TDP, we note that:

- Specific details regarding the information may not need to be predefined or predetermined in terms of location, medium, format, ownership, etc.

- One possible use of TDPs will be to serve as the technical element of a contractual business arrangement between the government and industry contractors to procure or re-procure, repair, support, or redesign an item. Typically, TDPs include information concerning an item's description, requirements, verification, and packaging [TDP 1992].

2.1.2 Mechanical-Based Systems

For our study, the term "mechanical-based systems" represents physical products that are not chemical, electrical, or electronic in nature, and which are described by three-dimensional (3D) geometric profiles and features including materials and physical attributes. Mechanical-based CAx tools are used to support product design, manufacturer, and assembly, and to analyze product performance in terms of stress, strain, kinematics, dynamics, and heat transfer properties. In mechanical design, an object's 3D size and shape are presented as a geometric model; and it might be rendered on paper as a sketch or drawing, or in a computer as a mathematical-based coordinate model.

(Note: While electronic design is not the focus of this study, it is useful to distinguish between mechanical and electronics design, which are typically performed as separate disciplines. Electronics involves a branch of physics that deals with the emission, behavior, and effects of electrons. Electronic-based systems are designs typically composed of multiple components, each with specific electronic performance characteristics, all interconnected to perform a predetermined function or to trigger a mechanical or electrical event. Electronic-based computer-assisted engineering and analysis tools provide logic synthesis, time-based simulation and response models, and performance analyses.

However, electronic systems design may need mechanical CAx tools for such things as designing enclosures, estimating cooling loads, and for defining physical layouts of circuit elements in geometric models. Although product technical data for mechanical-based systems is dominated by 3D geometric models (typically paper or computer based), product technical data for electrical/electronic-systems are a mixture of mechanical-based geometric data, electronic component interconnect book-keeping, and electronic functional simulation, modeling, and performance data.)

2.1.3 Adequate

We use the term "adequate" to describe a situation or condition barely sufficient to meet specific requirements. We caution the readers that the use of this term is not intended to imply that a situation or condition necessarily represented an optimum solution to specific requirements. Therefore, within the scope of this study, technical data or TDP will be adequate for procurement purposes if it is barely sufficient to meet the requirements of the procurement process.

However, the same technical data or TDP might not represent the most cost-effective data solution for the acquisition strategy selected because some details are lacking, for example. In our definition of a TDP, a TDP may represent the technical information that has

been delivered to a user as a package of data, or it may represent the projected sets of data that will be accessible and may be collected as a package of data at some future date.

2.2 Government and Industry Definitions

2.2.1 DFARS

The terms "technical data" and "technical data packages" may be interchangeable. Furthermore, if this perspective is adopted, both terms are consistent with the definition of technical data found in the contract clause for "Rights in Technical Data–Noncommercial Items," Section 252.227-7013 of the Defense Federal Acquisition Regulations (FAR) Supplement (DFARS):

> Technical data means recorded information, regardless of the form or method of the recording, of scientific or technical nature (including computer software documentation). The term does not include computer software or data incidental to contract administration, such as financial and/or management information [DFARS 1996].

2.2.2 Society of Automotive Engineers

The definition for TDPs has not changed substantially over the past thirty years. A 1967 report prepared by Gillespie and Armbruster [1967] for the Society of Automotive Engineers (SAE) stated that TDPs may be defined as

> that documentation containing all the design disclosure data, specifications, quality assurance provisions, and acceptance criteria necessary for the full and complete item description, item procurement, item manufacture, and item acceptance.

The SAE report cited the following four examples of typical TDP content.

- A performance specification[6] devoid of illustrations.
- A performance specification with illustrations and drawings.
- A design specification with its applicable design disclosure data.
- A single drawing with all requirements delineated or referenced thereon.

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6 While not necessarily germane to the definition of TDPs, this example cited the use of performance specifications—one of the main tenets of today's DoD acquisition reform initiative.

2.2.3 Army

The Helwig et al. report [1975], which came out of an Army study effort initiated in 1972, evaluated the use of a Pre-Production Evaluation technique to avoid undesirable consequences of errors and discrepancies in TDPs. This report acknowledged that technical data may exist in a variety of digital formats. The definitions from this report are as follows:

- **Technical data.** Technical data are recorded information used to define a design and to produce, support, maintain, or operate items of defense material. These data may be may be recorded as graphic or pictorial delineation in media such as drawings or photographic; text in specifications or related performance or design type documents; in machine forms such as punched cards, magnetic tape, computer memory printouts; or may be retained in computer memory.

- **Technical data package.** A collection of technical data products (items) which is complete for a specific use.

- **Procurement data package.** A collection of all data necessary for procurement of the items which it pertains, e.g., engineering drawings, specifications, manufacturing information essential to production, and test procedures.

In 1982, an Army management course on TDP development and management defined TDP as

> [a] technical description of an item adequate for use in procurement. This description defines the required design configuration and assures adequacy of item performance. It consists of all applicable technical data such as plans, drawings, and associated lists, specifications, standards, models, performance requirements, quality assurance provisions and packaging data and may range from a single line in a contract to several hundred or thousands of pages of documents [TDP 1982].

An August 1992 revision of the same course book, this time by the Army Management Engineering College, defines TDPs as

> that set of information that provides a technical description of an item that is adequate for the intended use of that data [TDP 1992].

The 1992 revision also uses the 1982 definition as a supporting description.

2.3 TDP Uses

2.3.1 Army

Both the 1982 and 1992 versions of the Army's TDP course book point out

> [t]he primary usage and purpose of the TDP is to manufacture a product from the data contained in the TDP.

In essence, TDPs serve as the technical element of a contractual business arrangement between the government and industry contractors to procure or reprocure, repair, support, or redesign an item.

These course books go on to observe that TDPs have many other applications for people in various disciplines:

> It is the engineer's basic instrument for technical analysis and evaluation.
> It is the Government contracting officer's means of providing an equitable basis for competitive bidding.
> It is the contractor's official documentation for bid purposes, for make or buy decisions, for estimating, for vendor item purchasing, for specialty house procurement, and for production engineering.
> It is the Government inspector's bible for acceptance of the item.
> It is the maintenance personnel's basic instrument for determining maintenance policy, and maintenance allocation.
> It is the cataloger's basic document for cataloging actions.
> It is the integrated logistics support (ILS) and supply personnel's basic documentation for developing supply support.

2.3.2 IDA

To realize the full range of potential benefits in concert with RBA initiatives, the IDA study team adopted a very broad definition of "post-production":

> The inclusive period after initial production of an item and throughout the remainder of the item's lifecycle.

This definition is more inclusive than a period beginning after cessation of end-item production, and would include products such as the F/A-18C/D aircraft (which is still in production and has been in various forms of production for approximately 18 years).

Under this definition, the post-production period in the case of the F/A-18C/D aircraft example begins after product qualification and contract close-out delivery of the aircraft from the initial production contract. We selected this post-production starting point because design ownership, production configuration, and configuration control authority will have likely been established. Furthermore, sets of technical data (e.g., TDPs) dependent on these details may be used in subsequent contractual actions such as procurement, reprocurement, spares acquisitions, etc.

3. Summary of Interviews

This chapter describes the results of our study interviews. Information is divided into two sections, the first one based principally on the results of interviews with both defense systems acquisition, support, and logistics managers; and the second section which is based on information obtained from CAx developers, suppliers, and users. Additional information from literature searches was included to supplement the interview results, and each situation is appropriately noted when this occurred.

3.1 Defense Acquisition, Support and Logistics Managers

We selected individuals to interview from the Services and Defense Logistics Agency (DLA) who had a variety of acquisition, support, and logistics functional responsibilities directly involved with weapon system technical data. Their functional responsibilities included the following:

- The definition of technical data requirements for new weapons programs.
- The use of technical data in acquisition and support.
- Assessment of technical data adequacy in accordance with Defense Spare Parts Breakout Program.

3.1.1 Defense Logistics Agency

Individuals interviewed at DLA pointed out that acquisition reform has yet to result in a wide-spread transition from build-to-print drawings to performance specifications in the operations of DLA. In fact, they observed that should the Services make a significant transition to performance specifications for post-production procurement, "DLA will not be in the game anymore" because of the following reasons:

- DLA inventory control points typically do not perform engineering that may affect the weapon systems.
- DLA lacks engineering data to assure new or altered item will perform properly in next level of assembly, or in all applications.
- Program offices or contractors are responsible for performance rather than DLA.

The DLA representatives also observed that nearly all legacy item TDPs are composed of build-to-print drawings (e.g., detailed drawings specifications). Furthermore, they expected this practice to continue in order to assure configuration compliance for such things as performance and safety.

However, on occasion DLA does support procurement without drawings or specifications. For example, while not the preferred practice, DLA uses Commercial and Government Entity[7] (CAGE) code and part numbers (P/Ns) to make sole-source purchases, sometimes requesting current configuration and P/N data from original equipment manufacturers. Under these circumstances, the part number becomes the TDP used for re-procurement.

The DLA representatives pointed out that there are inherent risks to the use of these procedures. As one example, they cited the potential that a specific part, bought to a performance specification and assigned to an existing stock number for a given performance specification item, might not work in all its potential applications.

3.1.2 Naval Supply Systems Command and Naval Inventory Control Point

During visits by the IDA study team, Naval Supply Systems Command (NAVSUP) and Naval Inventory Control Point (NAVICP) personnel made it clear that as result of acquisition reform, a new set of strategies for defense systems is being developed and implemented by the logistics support community. They indicated that these strategies look to long-term, sole-source contracts "to minimize risk."

However, several of those interviewed believe that the amount of data with limited rights will "skyrocket." They projected dramatic increases of data with limited rights directly associated with the new strategies. They attribute these expected increases to the use of COTS and non-developmental items (NDI), and the consequences of long-term delegation of design configuration control below major performance specification to prime contractors.

From a slightly different perspective, the interviewees noted that new strategies call for purchasing only the appropriate level and detail of data necessary to support a maintenance concept for the particular defense system. Based on these guidelines, we postulate that the government may not need to obtain technical data if maintenance is to be performed by a contractor in accordance with the approved maintenance concept for the defense system.

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[7] The CAGE is a five-digit code assigned to every government (design) agency or contractor.

For this situation, the NAVSUP and NAVICP personnel identified two preferred scenarios:

- **Scenario 1.** Involves items that are removed at the field or fleet organizational level of maintenance, and are sent directly to the contractor for repairs. Under this scenario, repair or replacement operations will probably be undertaken on a sole-source basis and the contractor will maintain configuration control.

- **Scenario 2.** Involves maintenance or repair of the item, performed at either the organizational or intermediate maintenance levels by Service personnel. The requirement here is for replacement items to be identical in configuration with the original parts. Under this scenario, there will be a tendency to follow past practices; that is, build-to-print drawings will likely be used, and DoD configuration involvement will be high.

The NAVSUP and NAVICP representatives discussed two areas of concern where the new strategy presented a potential for risk.

- **Increasing use of COTS and NDIs.** The representatives feared that DoD and the integrating contractor may not have requisite data rights or access to needed data. They lacked assurance regarding COTS and NDI configuration change control, upward compatibility of replaced COTS/NDI parts, and long-term support.

- **Verification and notification of changes.** The representatives pointed out that operating practices and procedures had yet to be developed for classifying major and minor changes when operating under the new performance-based acquisition strategies. With respect to major changes (Class 1), greater effort would be required when using performance specifications because all performance aspects must be completely verified concerning their effect on system operation and performance. For minor changes (Class 2), the representatives questioned the methodology for determining the change class type, and whether a change review would thoroughly address issues concerning performance and the logistics infrastructure.

Finally, the managers interviewed at NAVSUP and NAVICP stated that there was little or no change in practices, procedures, or data requirements specifically for legacy item TDPs as a result of recent acquisition reform initiatives. These TDPs were typically acquired in conjunction with the original weapon system development (or modification) and delivered to the program office at that time.

3.1.3 LPD-17 Integrated Product Team Logistics Manager

The LPD-17 Integrated Product Team (IPT) Logistics Manager pointed out that a contractor team will be providing a repository system to maintain all program data. It is expected that

- Data will be controlled and managed by the contractor team.
- All data will be digital (although formats have yet to be determined).
- The repository may include distributed data bases.

A goal for the program is that repository data be accessible to all that will need it, including the government. At the time of these interviews, the LPD-17 Program was early in its development, and all of the specific details for the data repository system had not yet been established.

The manager also noted it was essential that sufficiently detailed data be accessible as needed to support the adopted maintenance and support concept. Examples of what constituted sufficient data detail for specific situations included the following:

- Use of a performance specification when the contractor has configuration control and management, and parts removal, repair, and replacement responsibility.
- Use of a P/N and commercial manuals when data is not accessible (i.e., with the use of COTS products).
- Use of a detailed drawing (equivalent to Level 3 drawings) when the government performs repairs and when it has configuration control.

3.1.4 F/A-18 E/F Logistics Team

In contrast to the LPD-17 Program, the F/A-18 E/F Program is further along than the LPD-17. Consequently, its strategy for technical data is more developed.

In accordance with the technical data strategy being applied to the F/A-18E/F aircraft, system primes retain all data in a contractor-operated database over the program lifecycle, and the Navy is to have full access to this data. The objective of this strategy is to eliminate the following:

- Duplicate acquisitions.
- Re-development of technical data in unique formats.
- Government warehousing in a database.

The system primes' approach to eliminating duplicate acquisition is to retain data in the current format in their own databases, and make this data accessible to the Navy if needed. A more detailed description of this approach is provided in Appendix B of this document.

With respect to data rights, the program office expects all data developed under the contract to have unrestricted rights. Only data with unrestricted rights will be entered into the contractor-controlled database. However, clauses in the existing contracts permit contractors to challenge data rights at the time the data represents a final configuration state or is ready to be entered into the database. This clause has led to 50 challenges so far. The logistics team pointed out that only data from primes have been entered into the database. Data with limited rights is to be retained by the contractors owning the rights, and if the Navy needs this data in the future, it will be handled on a case-by-case basis under separate contractual action.

The logistics team anticipates that the ongoing changes in policy and practice will have noticeable changes on the Navy's maintenance and support strategy. Possible outcomes were cited:

- The Navy will isolate problems at the major assembly level (e.g., a black box), remove the item and send it to the contractor. The contractor will provide (1) assembly level maintenance to performance specification compliance; and (2) form, fit, function, interface (F3I) design configuration control.

- Performance specifications will promote greater contractor responsibility, and will likely lead to increased demand for two-level maintenance and F^3I upgrades.

- In part, because of enhanced reliability, less fleet/depot repair is planned.

The Navy representatives stated that although acquisition reform promotes greater contractor commitments, there is some concern that contractors may be reluctant to take on certain responsibilities or liabilities concerning two-levels of maintenance, reliability, and safety. At the same time, the representatives observed it unlikely the Navy would want to cede all responsibilities, such as safety, to contractors.

Additionally, while the notion of increased contractor repair under two-levels of maintenance is gaining support at Naval Headquarters, there exists intense interest at field and fleet locations to permit on-the-spot repair by Naval personnel. Furthermore, for some special or unique cases such as "battle damage repair," the Navy is possibly more experienced than the contractors. The final outcome of ongoing debates and strategy planning may influence the amount of data that will need to be accessible to fleet/field maintenance personnel.

Finally, the Navy representatives felt that data generated by contracts under the current performance specification regime was "as good or better" than that available under previous practices.

3.1.5 Warner Robins and San Antonio Air Logistics Centers

Warner Robbins Air Logistics Center

Warner Robins Air Logistics Center (WRALC) representatives noted that for them the principal barrier to full and open (F&O) competition using TDPs was a legal one associated with data ownership and rights. They based this observation on data from their Spare Parts Breakout Screening Program. The objective of this program is in accordance with the following DFARS clause:

> The objective of the DoD Spare Parts Breakout Program is to reduce costs through the use of competitive procurement methods, or the purchase of parts directly from the actual manufacturer rather than the prime contractor, while maintaining the integrity of the systems and equipment in which the parts are to be used [DFARS 1996, Appendix E].

The breakout process applies to parts that will be used as spare or repair items for a defense system, and that are likely to be acquired annually over a system's life cycle. Breakout is a multi-step process that screens the TDP to determine the adequacy of the TDP and the government's rights to use the data for acquisition purposes. As a direct result of this data screening, acquisition method codes (AMC) and acquisition method suffix codes (AMSC) are assigned to each part. These AMC/AMSC assignments provide the best possible technical assessment of how a part can be acquired. The technical assessments address factors such as

> the availability of adequate technical data, the Government's rights to use the data, technical restrictions placed on the hardware (critically, reliability, special testing, master tooling, source approval, etc.) and the cost to breakout vice projected savings [DFARS 1996].

The percentage data depicted in Figure 1 on the next page is based on the screening of all technical data packages at WRALC between January 1, 1991, through June 27, 1997.

- The upper parts representing COTS/NDI and F&O competition are the TDPs adequate for open competition.
- The remaining parts on the opposite side represent the barriers identified by WRALC: legal (limited data rights), economic (cost of alternatives), and missing data (technical data).

Furthermore, data reviews of all TDPs screened by WRALC during the past five fiscal years indicated that the adequacy of TDPs for F&O competition has not changed significantly (see Table 1 on the next page).

The data includes all items (parts and assemblies) managed by WRALC. These parts are typically electronic warfare subsystems, aircraft avionics, and missile systems and subsystems. (While our objective was to focused on mechanical-based items, it was not practical to isolate how many of these items were mechanical-based designs.) However, the WRALC data manager estimated that approximately 70% of the F&O competition

coded items were of a mechanical-design nature, and the remaining 30% were electrical/electronic. (This is discussed in more detail in Appendix A, Section A.3.8.2.)

In addition, the findings of the 1971 Army study [Griffiths and Williams 1971] that identified three barriers to using TDPs for competition are in very close accord with the summary data from the Spare Parts Breakout Program implemented at WRALC.[8] These three barriers are also legal (limited data rights), technical (missing data), and economic (cost of alternatives).

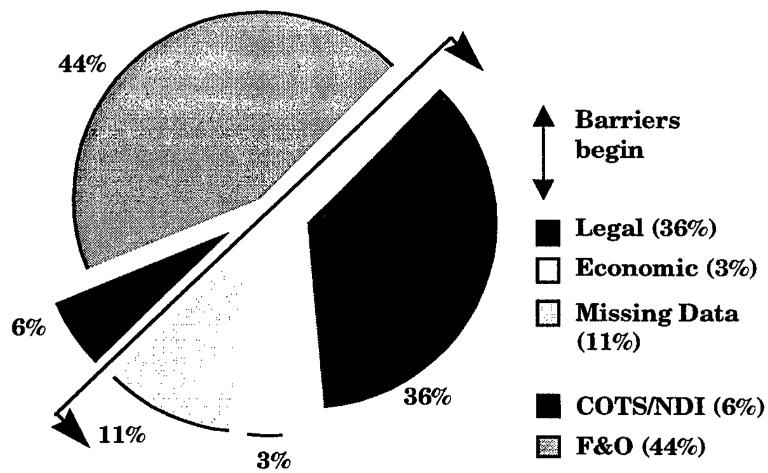

Figure 1. Barriers to WRALC TDPs

Table 1. TDPs Adequate for Full and Open Competition

By Fiscal Year					
1992	1993	1994	1995	1996	Through May 1997
45%	44%	51%	44%	47%	44%

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8 A more detailed discussion of this Army study and the adequacy of TDPs for competitive procurement are presented in Appendix A, Section A.2.

San Antonio Air Logistics Center

The San Antonio Air Logistics Center representatives pointed out that along with the benefits associated with performance specifications, there are potential risks, the two most visible ones being:

- Potential proliferation of configurations.

- The probability that reprocurement and repair will be sole-sourced to contractors owning the data.

3.2 CAx Developers, Suppliers, and Users

We selected individuals from organizations that were directly involved in the development and implementation of national and international CAx-based data exchange standards, and from a broad mix of the major CAx suppliers contacted at the M/CAD Expo 97.

3.2.1 National Institute of Standards and Technology

We met with representatives of the National Institute of Standards of Technology (NIST) to discuss advancements in CAx technology and the applicability of this technology to TDP content, exchange, and storage. Focusing on CAx exchange, the NIST representatives observed the following:

- Major improvements and accomplishments are available in CAx technologies, but there is still a long way to go, comparing the situation to "chasing a moving train." A neutral international standard is the approach for the future, i.e., STEP (Standard for Exchange of Product Model Data). As of this writing, IGES (Integrated Graphics Exchange Standard) is the best system but it lacks a robust capability to handle the new CAx solids technology. Currently, there is no parametric relationship exchange capability other than for native CAx in which the relationships were originally developed.

- "Native" CAx—that is, the original version in which it was written—is a risky alternative for long-term archival storage.

- A fall-back strategy of using available 2D images (IGES, raster, or paper) is still viable.

NIST representatives also observed that there are no commercially available CAx-based tools that capture design rationale or design intent, short of word processing tools which essentially replicate what "engineers put in their green notebooks."

Finally, when asked to comment on recommended TDP content, the NIST representatives stated that, to their knowledge, the most complete summary of what should be included in TDPs was presented in the 1971 Army study [Griffiths and Williams 1971]. (See Appen-

dix A, Section A.2, for more details.) The NIST representatives noted that today's CAx data falls well short of these requirements identified in this earlier study.

3.2.2 CAx Providers

The IDA study team interviewed a wide range of CAx providers at M/CAD Expo 97. All those interviewed made it clear that there have been significant gains in computer-assisted capabilities (e.g., CAD, CAM, CAE, Product Data Management). These gains have been driven by the computer revolution which has blurred distinctions between high-and mid-range systems.

As a result, software costs are declining rapidly. For example, mid-range CAD packages now range in price from $4,000 to $6,000, whereas the same capability cost over $18,000 just 18 months ago. Most advanced CAx systems are based on parametric solid modeling technology, and include capabilities such as finite element analyses, rapid prototyping, and design optimizing tools.

3.2.3 South Carolina Research Authority and PDES, Inc.

We had a joint meeting with the South Carolina Research Authority (SCRA) and the Product Data Exchange Using STEP (PDES), Inc. SCRA is a non-profit scientific and engineering corporation whose mission is to develop new technologies that enhance world-class manufacturing techniques. A significant area of its focus is in the CAx arena. PDES, Inc. is a consortium focusing on the development and implementation of electronic product data exchange standards.

The SCRA and PDES, Inc. representatives made the following points:

- While lagging the cutting edge of technology, the ability to exchange and manage data widely between different CAx architectures has vastly improved over what was possible just a few years ago.

- New integrated tools combined with solid modeling CAx technology help to identify errors.

- New mechanical CAx capabilities permit easier and much faster re-capture of mechanical design (average time is approximately 2.5 hours for most mechanical parts). On the other hand, the challenges are much greater for the re-capture of electronic design (e.g., average time for the re-capture of printed wiring boards climbed to 100 hours).

SCRA is a principal participant in the Navy's Rapid Acquisition of Manufactured Parts (RAMP) program. An early phase of the RAMP program was to demonstrate the re-capture of design data in a 3D solid modeling format. This was accomplished for a range of mechanical parts and printed wiring boards whose original designs were captured on paper or aperture[9] cards.

As part of its tasking on the RAMP program, SCRA reviewed a significant number of TDPs for accuracy of information. Among its findings were the following:

- Of the more than 1,000 TDPs for mechanical-based items reviewed by SCRA, all had some type of error.
- A similar review of 150 TDPs for printed wiring board provided the same result.
- While many of the errors found in the TDPs were mundane (e.g., typographic mistakes), a number of errors were very significant and would not have occurred had the designs been accomplished in the now available solid modeling technology.

In addition to tracking the shape of an object, modern CAx-based 3D solid modeling tools provide an analytical model of the volume embodied by the shapes. Consequently, mechanical designs produced on modern 3D CAx systems are less likely to have errors when compared to designs provided by hand or on older 2D CAx tools.

[9] Aperture cards are the old IBM punch card formats with 35-mm photographic negatives attached.

4. Vision of Future Lifecycle Support Practices

During the course of our analysis, we observed DoD entering a new era with greater levels of contractor representation for lifecycle support of defense systems. This observation helped to postulate our vision of future lifecycle support practices for DoD:

> System integrators and major subsystem primes are effectively becoming sole-source suppliers and program representatives (under contract to defense programs) for providing long-term sources of spare parts, maintenance, repair, and design configuration control of defense systems.

The new practices postulated in this vision are derived from multiple factors: acquisition reform initiatives, the restructuring of defense industry, the high priority assigned to COTS items, and a new defense policy giving preference to performance-based specifications.

Our vision of future lifecycle support practices is based on our observations garnered from our interviews and literature searches. This vision was the basis for the sponsor's decision to expand IDA tasking to include an analysis of contractor purchasing decisions, and is reflected in the three study objectives presented earlier in Chapter 1. In addition, we are supported by the findings from a recent report from the Defense Science Board on Vertical Integration and Supplier Decisions [DSB 1997]; these are reprinted at the end of this chapter.

4.1 IDA Observations

4.1.1 Developing and/or Procuring Performance Specifications

While performance specifications are not new, the emphasis given them represents a significant departure from past defense acquisition policies and practices. Secretary Perry's 1994 memorandum established a new DoD policy that called for greater use of

> ...performance and commercial specifications and standards in lieu of military specifications and standards, unless no practical alternative exists to meet the user's needs.

These policy changes have been further promulgated by the following: [10]

- DoD Directive 5000.1, Defense Acquisition [DODD 5000.1]
- DoD Instruction 5000.2-R, Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information Systems [DODI 1998]
- SD-15, Defense Standardization Program, Performance Specification Guide [SD 1995]

Finally, in addition to these documents, those interviewed who were associated with new systems acquisitions noted that performance specifications are being given the highest consideration and priority.

4.1.2 Arranging for Long-Term Support for Lifecycle Needs

Supply guidance in DoDI 5000.2-R states the following:

> [S]upport concepts for new and modified systems shall maximize the use of contractor provided, long-term, total life-cycle logistics support that combines depot-level maintenance along with wholesale and selected retail material management functions [DODI 1998].

Observed Service implementation on new programs was reported to be following this guideline. Representatives of both the F/A-18E/F and LPD-17 programs as well as NAVSUP emphasized that most of today's major new programs were awarded to a specific contractor or team of contractors through a very competitive acquisition process.

However, new programs and their respective IPTs have been empowered to do what makes sense, and the strategies that have evolved represent best approaches for individual programs. In most cases, preferred approaches are based on long-term, sole-source contracting strategies; and these strategies are being embodied in the program's acquisition and support plans. Those interviewed noted that up until just a few years ago, lifecycle sole-source maintenance arrangements were not viewed with the same favorable light.

4.1.3 Maximizing Use of Commercial Products and Processes

One of the principal effects of the Federal Acquisition Streamlining Act of 1994 was increased emphasis and preference for use of commercial items. The legislation established a new definition for commercial items, established preference for the acquisition of

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[10] A discussion of these documents is presented in Appendix A, Section A.3.4.

commercial items, and exempted commercial item contracting from many laws and regulations such as exemption for competitive purchases of commercial items from the cost and pricing data requirements of Truth In Negations Act [ESI 1995].

The Federal Acquisition Reform Act of 1995 further expanded the emphasis on satisfying government needs with commercial items through an expanded definition of commercial items, and a more robust commercial item exception to the requirement for obtaining cost or pricing data [ARTM 96].

These acts apply equally to issues regarding mechanical as well as electrical assemblies and sub-systems. As DoD systems use more commercial products or processes, DoD and contractors may need to pay additional attention to the accessibility and adequacy of data relating to these products or processes as the systems enter post-production phases.

4.1.4 Dividing Control Between DoD and Contractors

DoD will maintain design and configuration control to performance specifications while contractors will control detailed product designs. Secretary Perry's 1994 memorandum states the following:

> To the extent practicable, the Government should maintain configuration control of the functional and performance requirements only, giving contractors responsibility for the detailed design.

This policy has been promulgated through DoDD 5000.1, DoDI 5000.2R, and SD-15.

4.1.5 Minimizing Product Data Requirements

DoD will minimize product data requirements. However, if TDPs are needed, contractor data formats, media, and storage will be used. The goal of the CALS Program's IDE (Integrated Data Environment) concept is for the contractors to retain data in their own data formats and to implement mechanisms that will permit the Service users to access data if and only if needed [IDE 1996]. Program representatives noted that variations of this concept were being applied to the F/A-18E/F and LPD-17 weapon systems.

4.1.6 Repairing and/or Updating to Performance Configuration

Repair and/or update of design configuration will be to performance specifications; contractors will perform these tasks as a normal course of business. This opportunity was cited by the program representatives interviewed, and was held up as an example of the benefits to be realized from the combined collective effects of long-term contracting, increased use of performance specifications, and the delegation of design configuration control to contractors. The benefits are also cited in SD-15:

> The performance-based acquisition does not encourage the continuing reprocurement of the same item. It expects the Government to capitalize on the technical expertise and

> ability of the industrial community in order to procure products at continually improving levels of performance and reliability [SD 1995].

4.1.7 Proliferating Design Configurations

Design configurations will proliferate as a normal course of business; this will be one result of performance-based acquisition strategies. As indicated previously in Section 4.1.6, performance-based acquisition will likely result in alternative configurations with potential side-benefits of enhanced performance or reliability.

However, representatives interviewed noted that proliferation of design configurations can add risk and workload to maintenance actions when performed by Service personnel in field or at fleet locations (i.e., proliferation affects training and manuals as well as spare parts stock, control, and distribution, for example).

But if these same maintenance actions are performed by a contractor, with returned assemblies or subsystems in compliance with a performance specification, not only will the added risk and workload cited above not exist but the level of effort needed by field/fleet maintenance will be reduced.

4.2 Defense Science Board Findings

The general thrust of our vision is also reflected by some of the findings of the Defense Science Board Task Force on Vertical Integration and Supplier Decisions.

> The Department has significantly changed its buying practices since 1993. It is asking prime contractors to bid more comprehensive packages of mission and logistics requirements, and program managers are removing themselves from detailed oversight of their prime contractor's daily operations. These reforms are changing the dynamics between DoD managers, defense primes, and suppliers. DoD personnel have increasingly less interaction with suppliers or products below the prime level. Also, they are often unable to see the effects of their individual program decisions on the broader industrial capabilities. [DSB 1997, p. vii]

> The Department of Defense is also defining its weapon system buys differently, packaging pieces once bought separately into a single contract. Today it often requires the prime to be responsible for a more comprehensive weapon system mission package—to procure and integrate every system and subsystem across multiple mission elements (for example, air and ground elements). The Department often tasks prime contractors to provide management and logistics in later phases of the weapon system life. In focusing its interaction fully on the prime contractor and standing back to let primes manage broad areas, the Department is reshaping business opportunities in an industry already reordering itself by its increasing concentration. A few diverse primes have extensive resources and capability and are posturing themselves to be the leader in offering comprehensive "soup to nuts" management in their market areas....Firms who have traditionally contracted directly with the Department of Defense in some specialty subtier areas now rely on primes for a partnership or other entree into new systems. The Department and suppliers below the prime contractors increasingly do not interact. [DSB19 97, p. 34]

There is a trend towards awarding logistics support as a package back to a contractor. In many cases, this may be the weapon system "prime" who may have bid on the logistics support as part of a procurement or support contract option for some period of time. [DSB 1997, p. F-2]

5. Conclusions

Our conclusions are based, in part, on our interpretation of the consequences of recent changes to DoD policies and practices, CAx technologies, and the structure of defense industry. We also considered what the interviewees thought would be the effects of these changes upon acquisition and support.

For the convenience of the reader, the conclusions are grouped by their respective study objectives.

Objective 1. Identify changes to mechanical-based technical data content, form and media that will result from technical advances and recent acquisition reform initiatives

Conclusion 1. The 3D solid models produced by advanced CAx technology tools are improving technical data development, modification, descriptive capabilities, and long-term digitally stored data management and retrieval.

The broad application of computers to problems of design, manufacturing and engineering analysis is relatively recent. The computer revolution of the past thirty years has played a dominant role in advancing automated and assisted design, manufacturing and engineering capabilities, particularly in CAD, CAM, and CAE tools.

Improved CAx capabilities include shorter design times, enhanced design accuracy and quality, and new integrated design verification tools. These recent advances in CAx technologies are having a broad and direct influence on mechanical design and manufacturing.

- The number of CAx seats (installed CAx systems) for mechanical design and manufacturing is increasing in large measure because of the combined benefits of declining costs and increasing computer-assisted capabilities.

- Distinctions between high- and mid-range CAx systems are shrinking. This change is putting very powerful design tools, previously reserved for the costly design of a few complex assemblies, in the hands of nearly all designers.

- The broad range of CAx COTS integrated systems and third-party tool sets are providing a wide range of capabilities including rapid prototyping; photo-realistic rendering; direct CAM interfaces for milling, machining, or sheet-metal; weight, balance, and moment of inertia calculations; kinematic analyses; and finite element analysis tool interfaces.

- Initial design and modeling times are being reduced by an order of magnitude (if months, to weeks or days; if days, to hours). For example, as pointed out earlier in Section 3.2.3, more than a thousand TDPs were redrawn from legacy data formats in conjunction with the RAMP programs, and required an average time of only 2.5 hours for a designer using modern CAD tools to re-specify the design.

Technology advances have vastly improved data exchange capabilities between CAx systems. New COTS product data management and storage capabilities are permitting the growth of common data storage facilities. Advances in technology are eliminating the need to duplicate and manage data at multiple (redundant) contractor and defense facilities, making data more quickly available and accessible to users.

Three-dimensional solid models that are produced by modern CAx systems contain not only information about the shape of an object but they also provide an analytical model of the volume embodied by these shapes.

- Because the object is defined by an analytical model and all the design detail book-keeping is controlled by a computer, there is a much greater likelihood that the designed object is a topologically valid object.

- Furthermore, the new CAx 3D solid modeling systems apply the power of the computer directly to the design of parts and assemblies in addition to the lower-level functions such as drawing details.

- Consequently, solid models provide great insight for engineering analyses such as mass properties, interference and assembly modeling, kinematics, etc.

- The result: mechanical designs are less likely to have errors if produced on modern 3D CAx systems than if produced by hand or on older 2D CAx tools.

Conclusion 2. A very strong relationship exists between three types of data—performance specifications, detailed design drawings, and part numbers—populating TDPs and specific post-production acquisition and support strategies for which the data are needed.

We noted that for the post-development and post-initial production phases of a weapon system program, the use of particular TDP types is closely correlated with the implementation strategies presented by the Service representatives for procurement, maintenance, and support. In general we concluded that these relationships tended to be independent of the initial acquisition strategies used, specifically performance specifications, detailed design drawings, and part numbers.

- **Performance specifications.** These were typically associated with long-term support by contractors acting as representatives for the system program offices. The planned strategies we came across typically called for development and use of performance specifications at specific product levels where contractors will have repair or replace responsibility and configuration and design

control below the given product level. The assignment of these actions or responsibilities was expected to be sole-source; however, it may be competitive if very detailed performance specifications are available and cost savings are feasible. Very detailed performance specifications at lower levels of product assembly are expected to be a rare occurrence.

- **Detailed design drawings.** These were typically associated with competitive contracting for items with DoD-controlled design configurations or fleet/field product repair. When DoD performs repair and has configuration/design control, it acquires rights and access to design and manufacturing data/details (e.g., old Level 3 drawings). Detailed design drawings are typically used to competitively buy items as build-to-print.

- **Part numbers.** These were typically associated with sole-source acquisition when data rights or design control resides with contractors. Part numbers (P/Ns) are nearly always synonymous with or directly traceable to contractor drawing numbers. DoD obtains lists of part numbers (and access to drawings unless contractor will not provide them) when data rights, design details, or configuration/design control do not reside within DoD. Typically, strategies applying sole-sourcing with P/Ns are used to identify items to be acquired when DoD does not have drawings (or drawing data rights) and when assured configuration compliance is desired due to maintenance strategy. For example, under the Spare Parts Breakout Program, a part or assembly may be identified by P/N and acquired sole-source from the actual manufacturer that is not necessarily the system prime.

Objective 2. Assess if future mechanical-based technical data will be adequate for DoD or contractor competitive procurement

Conclusion 3. Emerging acquisition strategies will likely reduce overall adequacy of future TDPs for competitive procurement of products and services by DoD.

Adequacy is defined by Webster [1988] as the state of being at least barely sufficient or satisfactory to meet requirements. In evaluating TDP adequacy, we needed a context that includes requirements to be met. While the intended purpose of TDPs may vary widely, our study focused on the primary usage and purpose of TDPs as stated in the Army Management Engineering College's course book [TDP 1992], "to manufacture a product from the data contained in the TDP." The adequacy of a specific TDP and/or package of accessible technical data must be evaluated in terms of the context in which it will be used. From this perspective, we set out to compare the relative adequacy of past and anticipated future TDPs for use by DoD organizations in competitive procurement. The observed technical aspects of documentation required for TDPs to be adequate for post-production competitive procurement by defense organizations are summarized in Table 2 on the next page.

Simply stated, the technical content of TDPs to be adequate for competitive procurement must include the *description* of an item, the performance *requirements* for the item, and the *verification* details needed to certify that the item meets stated performance and description requirements. The specifics needed for each of these three content items (description, requirements, and verification) typically vary, depending on whether a performance-based acquisition approach or detailed-design based acquisition approach is used. Because of its importance to contractual action, an additional discussion on verification requirements such as quality assurance, testing, and inspections is included in Appendix C of this document.

Table 2. Technical Aspects of Adequate TDPs for Competitive Procurement

	Performance-Based Approach[a]	Detailed Design-Based Approach[a]
Underlying intent	Make/produce item to requirements	Make/produce item like the others (i.e., the drawing)
Characteristics of the item description or product specification	Complete performance requirements for intended use[b] All necessary interface and interchangeability characteristics needed for intended use[b] Engineering drawings are used as a communicating convenience, and only to the extent necessary, to identify physical characteristics of F3I. Quality assurance requirements and provisions	Detailed description of parts and assemblies (usually prescribed by engineering drawings)[c] • Delineate completely all aspects of product and all subassemblies necessary for F3I replication of "as designed" item • Specialized materials or unique processes to be avoided—but if necessary, must be fully detailed so as to be reproducible by another competent manufacturer • Details sufficient and in standard or de facto standard formats so that data are not restrictive to another competent manufacturer Performance requirements & corresponding tests/inspections to assure proper fabrication, adjustment, and assembly

a Note: All details must be free of any limited rights data. This constraint assures data may be used for competitive procurement.

b Intended use includes maintenance infrastructure and application unique environments.

c Requirements are embodied by design and reflected in the instantiation prescribed by the drawing.

Given the technical aspects of what is needed for adequate TDP documentation, we focused on situations for which TDPs exist, the items to be procured are in the post-production phase of their lifecycles, and competitive procurement by DoD organizations between current and alternate competent manufacturers are planned.[11]

With these situations in mind, we identified four conditions that were put forward from the interviews as the likely effects of emerging acquisition strategies. *If any one of these conditions occurs, it may tend to reduce post-production competition between current and alternative competent manufacturers.*

- Overall percentage of data with limited rights are likely to increase.
- Long-term contractual representation (sole-source) arrangements are being planned.
- Performance-based acquisition strategies will tend to assign design and configuration control responsibilities to the original contractors.
- Technical data for items below existing performance specifications are typically not available, and cost is added for developing data (e.g., subtier performance specifications and requisite quality assurance provisions).

However:

- These four conditions do not necessarily preclude competitive procurement of post-production products and services by contractors acting as representatives for DoD system program offices.
- Furthermore, contractual representatives in all likelihood will have been selected as a result of competition.

This having been said, the following conclusion addresses the adequacy of future TDPs under long-term arrangements where contractors act as representatives for DoD system program offices.

Conclusion 4. For situations where contractors retain data rights or control design configurations, the relative quality and adequacy of TDPs will be as good or better than for TDPs retained by the government in the past.

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[11] Regarding "TDPs exist": This would include situations where needed technical data are accessible to the DoD buying organizations—as might be the case with a contractor-managed data repository.

The principal rationale behind this conclusion is that for TDPs with limited rights data, the prime contractors will be more likely to own the data rights than will the government. Furthermore, the prime contractor will likely be assigned design configuration control as a result of the acquisition reform initiatives. These contractors likely will have supplemental engineering data pertaining to items below existing performance specifications that are typically not included in TDPs.

New business strategies under acquisition reform do not dictate how a contractor representative will supply spare and repair parts (e.g., acquire by competition, acquire as sole-source or manufactured in-house). However, potential higher spare parts costs (attributed to agent pass-through charges or non-competitive purchases) may be offset by elimination of duplicative government functions of data storage and management, spare parts item management functions, and evolutionary product improvements through agent-managed performance-based acquisitions.

Finally, data quality and accuracy improvements are independent of ownership and control, and have been driven by CAx technology advances. (This was addressed in more detail in the Conclusion 1 discussion.)

Objective 3. Identify the mechanical-based technical data that DoD will need to support the functions of buying, modifying, and maintaining post-production products.

Conclusion 5. Technical data are adequate if they meet requirements of the specific intended post-production use. This use may be characterized by three distinct situations:

- Design configuration control of assembly by DoD or contractor(s).
- Maintenance or support of assembly performed by DoD or contractor(s).
- Competitive or non-competitive procurement of replacement parts(s) or parts support.

Given that some amount of technical data will be available at the conclusion of any product development or initial production, we asked those interviewed to comment on the adequacy of the available TDPs. Invariably, the response was a variation of the following: *TDP adequacy is dependent on situations by which an item is to be acquired.* For example, a part number is generally adequate for sole-source or COTS item acquisitions. In contrast, detailed drawings with full design and manufacturing process disclosure are typically inadequate if containing limited rights data.

Yet the situations by which an item is to be acquired are strongly influenced by specific acquisition strategies to be used over the post-production lifecycle of the product. Based on a composite of our own observations showing similar best practices being applied to common situations, we identified a common set of guidelines (Table 3 on the next page) applicable to many programs. These guidelines may be used to assist future programs to delineate technical data requirements and help managers plan for potential changes that

may occur over a system's lifecycles. (Examples of changing conditions in a potential industrial base, acquisition strategy, or support include lost sources of supply, different maintenance and repair levels, and increasing competition.)

Table 3. Strategy Guidelines for Tailoring Technical Data Requirements to Situation-Dependent Needs

Unique Situations at Each Product Assembly (Eight Potential Situations for Each Part, Assembly, etc.)				Strategies for Assuring Technical Data Will Be Adequate in Each Situation
#	Competitive Procurement	Design Configuration Control	Maintenance	General Data Strategy to be Applied at Each Assembly Level
1	Yes	DoD	DoD	• Detailed drawings with data rights *or* • Performance specs[a] plus logistics F^3I requirements[b]
2	Yes	DoD	Contractor	• Detailed drawings with data rights *or* • Performance specs
3	Yes	Contractor	DoD	• Performance specs plus logistics F^3I requirements
4	Yes	Contractor	Contractor	• Performance specs
5	No	DoD	DoD	• Drawings (not critical that all details and processes available nor that data have unlimited rights) [c]
6	No	DoD	Contractor	• Performance specs plus drawing changes[d] *or* • Drawings (not critical that all details and processes available nor that data have unlimited rights)
7	No	Contractor	DoD	• Performance specs plus logistics F^3I requirements
8	No	Contractor	Contractor	• Performance specs

a Performance specs are (1) form, fit, function requirements at the assembly level, and (2) interface and performance requirements allocated from the next higher level of assembly.

b Logistics F3I requirements refers to any additional performance and interface requirements associated with the logistics infrastructure when the item is used (e.g., support equipment, manuals, training).

c Implies that total design, engineering know-how, or unique manufacturing processes may be less than fully disclosed in the data, or the documentation may include limited rights data.

d The statement "plus drawing changes" implies that changes to drawings will be coordinated with DoD and approved by the responsible DoD agent.

We matched sets of suggested technical data strategies used by the programs interviewed with the three anticipated acquisition lifecycle conditions of *competitive procurement*, *design configuration control*, and *maintenance*. Because there are three independent situations, each with two alternatives, there are eight unique lifecycle strategy conditions that may occur at each level of product assembly (e.g., part, assembly, subsystem).

The first column (labeled "#") is used only for convenience's sake, to label each of the eight unique conditions at the specific item level.

The next three columns (Competitive Procurement, Design Configuration Control, and Maintenance) identify the specific acquisition lifecycle attributes that pertain to each of the unique strategy conditions.

The fifth and last column identifies possible strategies for which available data would be adequate to meet the data's intended use as constrained by the unique lifecycle strategy conditions that may occur at each level of assembly. These unique lifecycle strategy conditions depend on how replacement units at each level of assembly are procured, controlled, and maintained. The correlation of each specific technical data strategy tends to be associated with case-specific acquisition lifecycle attributes pertaining to the item in question. While not totally identical, the end effects of design configuration control and maintenance) have some striking similarities when DoD assumes responsibility for one, the other, or both.

To use this table, first identify the likely acquisition lifecycle attributes that apply to the specific product assembly in question. This can be a component, an assembled part, a complex assembly, or a major subsystem.

Then simply select one of the eight rows that applies in this situation. Follow the row across to the corresponding data strategy guideline in the last column. This strategy, or in some cases sets of alternative strategies, is intended as a starting guideline for use by acquisition strategy planners or IPT members during trade-off discussions and analyses. The remainder of this chapter discusses the correlation between the technical data guidelines and situation attributes identified by us.

Competitive procurement. In all cases where competitive procurement was pursued, there were no restrictive issues regarding data rights or proprietary data. This was identified as an essential and necessary constraint for competitive procurement. However, while the lack of data rights clearly restricted competitive procurement, situations were identified where even though DoD may have unrestricted data rights or licensed data rights, noncompetitive procurement action was pursued. For these situations, other programmatic considerations tended to influence the selection of a noncompetitive acquisition strategy.

Design configuration control. DoD design configuration control is typically used when actual configuration details—as manufactured and as installed design—are considered critical to assure specific needs are met. Examples of such needs include safety, operational certification, standardization or compatibility across multiple models, rigid adherence to specific maintenance or application procedures, and cost containment associated logistics requirements.

The design configuration control attribute also addresses who (i.e., DoD or contractor) is responsible for assuring the new or alternate designed item will function properly in the system in all intended environments. In some instances, the assurance may require detailed qualification testing while in others this assurance may be provided with relatively simple analyses.

DoD design configuration control may be invoked under any of the identified data strategies, and focuses principally on tracking of approved configuration details and approving/authorizing changes to the configuration baseline. Typically this is associated with detailed drawings. However, DoD design configuration control requirements may be invoked with part numbers or performance specifications—providing legal or contractual arrangements assure the item will not change without authorization in accordance with agreed-upon control procedures.

Maintenance. If the item (e.g., part, assembly, subsystem) may be removed, serviced, or repaired by DoD personnel while performing organizational or depot-level maintenance, there is a desire that the replacement item be identical to the old item. Alternately, if the replacement item is not identical, then it must be fully compatible in terms of F3I and must be fully compatible with logistics F3I infrastructure requirements. These logistics requirements may include additional F3I requirements associated with special maintenance environments, maintenance tools, maintenance manuals or procedures, and necessary personnel training or certification. The most significant distinction between contractor and DoD personnel performing maintenance at the item level is that the contractor must assumes responsibility for logistics F3I as a part of performing maintenance at that level of assembly.

6. Recommendations

Recommendation 1. Adopt systematic mechanisms to assess data needs. DoD should adopt mechanisms to systematically assess near- and long-term technical data needs, and identify optimum lifecycle strategies to accommodate changing conditions.

The present technical data guidance in DoDI 5000.2-R is very general, consisting mostly of top-level goals and objectives:

> Each PM (program manager) shall develop and document an acquisition strategy that shall serve as the roadmap for program execution from program initiation through post-production support [DODI 1998].
>
> Preference shall be given to the use of commercial items first and non-developmental items second. However, the overriding concern is to use the most cost-effective source of supply.
>
> Beginning in FY97, all new contracts shall require on-line access to, or delivery of, their programmatic and technical data in digital form, unless analysis shows that life-cycle time or life-cycle costs would be increased by doing so. Preference shall be given to on-line access to contractor developed data through contractor information services rather than data delivery....Solicitations shall require specific proposals for an integrated data environment to support systems engineering and logistics activities.

Guidelines in the Defense Acquisition Deskbook are very good as far as they go. The guidance found in the Deskbook begins to identify areas the program manager or IPTs should address when defining technical data solutions that

> minimize the time and cost of satisfying an identified, validated need, consistent with common sense and sound business practices [DAD 1997].

This is also the primary goal in developing an acquisition strategy, as defined in DoDD 5000.2-R. However, these guidelines are void of case-specific strategies or templates that suggest when and why data are typically needed over a weapon system lifecycle.

Most of the individuals interviewed said they wished they had had recommended guidelines and strategies when they were tailoring TDP requirements. Yet, as presented in the conclusions, the reported technical data implementation strategies for different programs tended to correlate very closely with the types of data populating TDPs, and the strategies tended to be dependent on three acquisition lifecycle conditions:

- Whether the procurement was competitive.
- Who controlled the design configuration.

- Who performed maintenance.

Based on the composite of observations showing similar best practices being applied to common situations, we believe a common set of guidelines applicable to many programs is feasible. We matched sets of suggested technical data strategies for mechanical-based items with the three anticipated acquisition lifecycle conditions. We developed guidelines (Table 3) for defining what data are needed to be adequate (barely sufficient or satisfactory) to meet requirements for mechanical-based systems for each of the eight unique and situation-dependent acquisition and support strategies.

While it is unlikely that a single strategy or guideline will address all potential technical data requirements that may occur, we recommend that guidelines of this nature should be developed. Furthermore, these guidelines should be given to acquisition strategy planners as one of several options.

Recommendation 2. Evaluate data guidelines for other product categories. DoD should evaluate alternative technical data guidelines applicable to other than mechanical-based product categories.

We believe that our suggested guidelines, or some very similar guidelines, may be applicable to other product categories such as engines, hydraulics, and electronics. We recommend that an appropriate future course of action in developing technical data guidelines should include an IPT specifically chartered to investigate technical data strategy guidelines as options to be added to the Defense Acquisition Deskbook.

Appendix A.
Factors That Affect the Adequacy of TDPs

Contents of Appendix A

A.1 Introduction

In this appendix we describe and summarize the factors that have historically affected TDP adequacy. In our assessments that follow, we then describe the effects that recent changes in technologies, policies, and procedures may have in the future.

In Section A.2, Barriers to TDP Adequacy for Competitive Procurement, we discuss the legal, economic, and technical barriers to competitive procurement of systems, spare parts, and support capabilities. The work contained in this section is drawn largely from the 1971 Army study [Griffiths and Williams 1971]. We selected this 27-year-old Army study as the foundation for our analysis for the following reasons:

- Little has changed to indicate that the major barriers to competitive procurement have been altered significantly.
- The analysis framework used in this Army study provides a rigorous approach for evaluating the effects current factors might have on competitive procurement.

In Section A.3, Effects of Technologies, Policies, and Procedures, we apply the analysis framework used in the Army study, and discusses the effects of new technologies and changes in defense acquisition policies and practices on TDP competitive procurement barriers. We also provide short assessments of the subject material.

A.2 Barriers to TDP Adequacy for Competitive Procurement

In this section, we discuss the types of barriers—legal, economic, technical—that DoD faces. The legal and economic barriers are relatively straightforward, and only require a short description. However, the technical barriers are complicated, and must be described from several perspectives.

A.2.1 Legal Barriers

Legal barriers tend to exist when DoD has less than unlimited rights to technical data needed for a competitive procurement action. These barriers can result from the source of funding and the respective rights of all parties. These rights are an extension of a party's funded activities and the ownership of data or patents that might result. The effects of legal barriers may be reduced by various techniques:

- Substitution.
- Circumvention.
- Purchases of the rights to the data or patents.
- Use of performance specifications (form, fit, function) rather than a specific design solution.

The Army 1971 study viewed the legal barriers as relatively benign ones.

> It is a relatively acceptable barrier, even though it limits competition. It elicits conformance rather than attack because it is recognized and controlled by the principles, policies and laws relating to patents and limitations upon rights in data. Such rights tend to flow to the party that funds the conception and development of the technical information. Theoretically, both Government and industry benefit from the protection of patents and rights in data [Griffiths and Williams 1971, p. 2].

A.2.2 Economic Barriers

Economic barriers result from the relative cost of acquisition alternatives (e.g., competition or sole-source procurement). These barriers are tolerable only when it is clearly not feasible or not cost effective to strive for competition. Consequently, economic barriers are frequently countered through various means.

> By "breaking out" components for direct or competitive purchases; by using the techniques of multi-year procurement; by performing advanced production engineering efforts to enhance competition potentials; by emphasizing competition alternatives and

thereby planning for down-stream competition early in the materiel life cycle [Griffiths and Williams 1971, p. 2].

A.2.3 Technical Barriers

Technical barriers result from the difficult task of communicating design and production technology to firms that were not engaged in the original research and development or previous production efforts.

> It is merely a matter of communication—of transferring information legally owned and determined to be cost effective for transfer from one source to another. In this connection, the Government has evolved the policy to acquire the developer's technical data, which was conceived and developed by public funds, and then furnish it to the market place of prospective suppliers to solicit competition for items identical in design to that of the developer or previous producer. The Government usually acquires such technical data at the time it decides to reprocure the equipment. It attempts to acquire only the type and quantity of data that is necessary in view of its intended use [Griffiths and Williams 1971, pp. 2, 3].

This same study goes on to observe that communication of the technical information may break down for two different reasons:

- Inadequate TDPs were acquired.
- The transmission of reprocurement technical requirements was ineffective.

This argument—giving merit to these two different viewpoints—is drawn from examples where a specific TDP is successfully used in one competition, and later when the same TDP is used on a subsequent competition, the procurement results are less than fully satisfactory. The Army study identified a number of major factors relating to both of these viewpoints, and these factors are discussed in detail in the following subsections on technical barriers.

A.2.3.1 Acquisition of Inadequate TDPs

The Army study asserts that the process by which the government acquires technical documentation is faulty. The consequences of this faulty process are depicted in example problems taken from Griffiths and Williams [1971, pp. 35-38].

> **Know-how not captured.** The full design and manufacturing technology of a highly complex item cannot be fully disclosed and documented. Some marginal degree of knowledge (e.g., tidbits of operational information) which might be "know-how," will always be locked in the memories of key people and will never be amenable to documentation. Esoteric practices that exist within the plant of the developer or previous producer are also not subject to documentation. Minor improvisations of the bench level machinist or assembler to achieve acceptable item performance (and to help the design engineer out of a dilemma) may never filter back to the designer for incorporation into

the data package. Commercial improvements to vendor specialty parts may conflict with other parts of the equipment. To the extent that such knowledge is essential to successful reproduction of the equipment, the documentation package will remain inadequate.

Latent errors. The voluminous mass of data that is typically necessary in reprocurements of military design equipment equals a required degree of specificity that is unrealistic when one considers that human beings must set forth such documentation. To render it error free and purified of defects is a near superhuman task.

Checking and verification errors. The people responsible for checking, reviewing, inspecting, and accepting the voluminous data set forth in exacting detail are implicitly charged with a similar near superhuman responsibility. To perform their task to the utmost would demand reverse engineering and duplication of each minute computation and decision.

Process details not captured. Except where a process is known to be essential, the procuring activity does not attempt to dictate the processes of fabrication, assembly, and test; it desirably and deliberately solicits entrepreneurial ingenuity from the various competitors....But the documented technical data of one firm may not be relevant or compatible with the needs of another firm.

Lagging configuration changes. The very nature of equipment developed peculiarly for military is such that the documentation of the design, production engineering, and quality assurance provisions are typically in a relative state of flux just at the time competitive reprocurement is planned....To the extent that approved changes or even planned changes to the data are not incorporated into the reprocurement data package, it will in fact, be inadequate for production of the desired equipment.

Incomplete design disclosure. The motivation of the developer of the documentation works at cross purposes under some conditions. On the one hand, he naturally desires to perform well under his contract and yield a "high quality" TDP: on the other hand, he may be motivated to enhance his position as a competitor for the follow-on reprocurements—which may induce him to "drag his feet" and reluctantly furnish something less than a "high quality" set of documentation.

Inclusion of proprietary data or markings. The stimulus of motivation of the developer of the TDP may encourage him or his sub-contractor to include proprietary data in the item he is developing; or to utilize proprietary components where non-proprietary components would serve equally well; or to classify and mark data as proprietary when in fact it is not.

Limited experience preparing reprocurement TDPs. If the research and development contractor is distinctly "development" rather than "production" oriented, this too, it is alleged, can influence the adequacy of the data package.

A.2.3.2 Ineffective Transmission of Reprocurement Technical Requirements

The 1971 Army study asserts that the process by which the government and contractors transmit and use technical documentation to procure hardware is faulty. The consequences of this faulty process are depicted in example problems taken from Griffiths and Williams [1971, pp. 39-42].

> **Contractor capabilities not matched to TDP requirements.** If the procuring activity selects a new contractor that is a marginal or poor producer, the relative adequacy of the TDP is not likely to alter his pattern of performance.... Thus, a common opinion is that a "good" TDP in the hands of a "bad" contractor will likely result in a "bad" contract; and a "bad" TDP in the hands of a "good" contractor will likely result in a "good" contract. This opinion holds that it all depends upon who is interpreting and using the technical documentation.
>
> **Potential of underbids and buy-ins.** Adverse motivational pressures can be created when an anxious offeror quotes a price too low as a result of: (a) over optimism; (b) underestimating the necessary man hours, material, tooling, complexity, or leadtime; (c) perceiving an "opportunity" to enhance his profit potential. Such a condition can also be created when a potential contractor deliberately underbids and "buys-in" either on price or the time schedule, hoping to recover from his adverse posture during contract performance. In short, such a contractor may initially or subsequently plan to "get well" on modifications to the contract; accordingly, he may plan to find fault with the TDP. Historically it has not been especially difficult to locate the existence of defects and justify demands. Usually it was a simple matter of selecting a drawing and charging an engineer to find a defect that is negotiable.
>
> **Need for a diversified pool of engineering talent.** All reprocurement actions do not consist of neatly arranged configurations and time phased production baselines. Many actions are assemblages of varying items and components in differing states of descriptive readiness. Marginal increments of additional design, production, and test engineering are not infrequently required in such cases to successfully produce the equipment. Such increments of extra effort are not necessarily exotic requirements. But a qualified and perhaps diversified pool of engineering talent is desirable and often a necessary prerequisite to successful performance of such a contract.
>
> **Conditions of use not as initially intended.** It is also pointed out that certain environmental circumstances often preclude "steady state" contract performance. The terms of some contracts are not necessarily compatible with mission objectives. Priorities and motivational pressures are often conflicting.... If the conditions of use are not as initially intended, effective transmission of procurement technical requirements is seriously impeded.

A.3 Effects of Technologies, Policies, and Procedures

Advances in technologies and recent changes to defense acquisition policies and practices have affected the TDP competitive procurement barriers presented in Section A.2. We discuss the effects of individual technology advances and changes that are the consequences of acquisition reform. Each advance or change may have a separate effect on those barriers and factors.

As a convenience to the reader, we have provided the titles of these individual subsections as headers.

A.3.1 Preproduction Evaluation Concept

A.3.1.1 Summary

The Preproduction Evaluation (PPE) Concept was defined in Army Materiel Command Pamphlet 715-6, and has been used principally by the Army since the 1970s. The rationale for the PPE is described separately in an Army course book, *Technical Data Package Development/Preparation* [TDP 1992].

> There has been growing doubt within the Department of Defense that a TDP can be prepared for complex items and systems, by either the Government or by development contractors, which will be sufficiently complete, accurate, and definitive to be truly suitable for competitive initial procurement. In case after case, production costs have escalated to incredible proportions, and production has been delayed for months, and even years, as a result of engineering changes in the initial production contract. The PPE concept was, therefore, developed to increase the probability of successful initial production in a competitive environment [TDP 1992, p. 10-34].

When the PPE Concept is used, a PPE contract is awarded that requires the contractor to conduct a review of the detailed TDP and certify that it is suitable for the contractor's use. The PPE contract proceeds the contract expected to use the TDP.

> The contractor's certification takes the form of an agreement that he will meet the end item performance requirements after compliance with the Government's detailed technical data package and any revisions found necessary during his review [TDP 1982, p. 10-26].

A.3.1.2 IDA Assessment

The PPE Concept focuses primarily on technical barriers. By its very nature, the PPE Concept should permit both the government and contractor to consider each of the factors identified in Section A.2 of this appendix. Interestingly, an evaluation of the PPE concept by the Army in 1975 concluded that the PPE Concept was not generally understood and, consequently, provided ten specific guidelines for better application [Helwig 1975]. **Note:** An analysis of the effectiveness of this concept was not conducted as a part of this present study.

A.3.2 Rights in Data

A.3.2.1 Summary

The government and industry have different interests concerning technical data rights. If the government is not the owner of technical data or does not have the right to authorize others to use technical data, it faces legal barriers for using TDPs in competitive procurement. The Federal Acquisition Regulation (FAR) recognizes these competing interests regarding rights in technical data. "Unlimited rights" as used in the FAR

> means the rights of the Government to use, disclose, reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, in any manner for any purpose, and to have or permit others to do so [FAR, Part 27].

"Limited rights data" means the data

> embodies trade secrets or are commercial or financial and confidential or privileged, to the extent that such data pertain to items, components, or processes developed at private expense, including minor modifications thereof [FAR, Part 27].

Laws and regulations regarding rights in data have changed significantly over the last fifty years. During the 1940s, data rights were governed by a single paragraph in the Patent provisions and essentially granted all rights to the government. In 1947, this same paragraph was included in the Army Procurement Regulations [Nash 1994].

In 1957, in response to industry concerns, DoD updated the data rights clause which is now in the Armed Forces Procurement Regulation. This provided an exception for limited rights, requiring the government to gain permission of the contractor prior to the use of this data for manufacturing or procurement of spares.

Industry gained further concessions in 1958 with a clause that

> allowed contractors to exempt from the data package information pertaining to commercial items or items developed at private expense. This clause defined proprietary data as the contractor's secrets of manufacture that could not be discerned from product inspection and which were protected by the contract from unrestricted use by others [Hale 1985, pp. 42–43].

In the early 1980s, the adverse publicity from the procurement of spare parts at excessive prices created a major turn-around in DoD data rights policy:

> Secretary of Defense Weinberger issued a blanket deviation to the technical data regulation which allowed the military Services to adopt a variety of policies to obtain greater rights in technical data. Congress then enacted new statutory requirements as part of the Defense Procurement Improvement Act of 1984, stressing the need to acquire data for competitive procurement of spare parts [Nash 1994].

The Competition in Contracting Act of 1984 permitted the government unlimited rights to technical data and computer software in the performance of a contract. However, the 1986 Packard Commission Report observed that the new unlimited data rights practice discouraged firms from participating in defense markets [Nash 1994]. Later that year, Secretary Weinberger rescinded the data rights deviation he had previously granted. Subsequently, Title 10 of the U.S. Code was amended by Public Law No. 99-661, prohibiting the government from requiring a contractor to sell or otherwise relinquish data rights that had been developed at private expense as a condition of contract solicitation or competitive award.

In April of 1987, President Reagan issued an Executive Order allowing contractors to retain commercial rights with respect to technical data and computer software developed as part of government contracts [Nash 1994]. FAR provisions concerning mechanical design data rights have remained largely unchanged since 1987.

Restricted rights pertaining to computer software were instituted in the mid-1990s, and are of similar form and intent to those provided for in the technical data rights provisions.

A.3.2.2 IDA Assessment

A legal barrier to using data in competitive procurement by DoD clearly exists any time a TDP contains data with *limited rights*. If competitive procurement is still desired, the government will need to investigate alternative acquisition strategies for the items or assemblies with restricted data (e.g., substitution, circumvention, purchase of the data, use of performance specifications). The technical risks and the increase in costs associated with an alternative strategy may introduce additional economic and technical barriers to competitive procurement. These additional barriers must be considered as well.

A.3.3 Acquisition Reform Legislation

A.3.3.1 Summary

Government rights in technical data have been addressed in the context of acquisition reform by the Federal Acquisition Streamlining Act (FASA) of 1994 and the Federal Acquisition Reform Act (FARA) of 1995. Additionally, the Competition in Contracting Act (CICA) of 1984 has had a significant influence on modern defense acquisition policy. These acts will be discussed within this section as they relate to the potential for competitive procurement.

CICA legislated that federal acquisition programs require *full and open competition* to the fullest extent practical. It also required a structured approach for exempting the requirement when noncompetitive biding procedures may be invoked. CICA opened up sole-source acquisitions to competitive procurement [OTA 1991].

FASA established a new definition for commercial items, created a preference for the acquisition of commercial items, and exempted commercial item contracting from many laws and regulations (such as exemption for competitive purchases of commercial items from the cost-and-pricing data requirements of the Truth In Negations Act). The simplified acquisition threshold for small business awards was increased to $100,000, and these purchases were exempted from 13 laws that were restrictive in nature and were otherwise applicable to all federal procurements.

FARA further expanded the emphasis on satisfying government needs with commercial items through an expanded definition of commercial items, and a more robust commercial item exception to the requirement for obtaining cost or pricing data [ARTM 96]. FASA also directed that a government-wide Federal Acquisition Computer Network for electronic commerce be established [ESI 1995].

The effects of FASA were principally seen in three areas: (1) simplified acquisition threshold (for small business); (2) increased emphasis and preference for commercial items; and (3) increased emphasis on electronic commerce capabilities.

A.3.3.2 IDA Assessment

By placing emphasis and priority on competitive purchases of commercial items, the government though its acquisition reform legislation has created the potential of changing the degree and level of technical detail available to the government for use in a TDP. For example, commercial items will likely increase incidences of (1) TDPs with limited rights data, and (2) TDPs void of performance specifications of the product and/or void of detailed technical design data (e.g., a commercial manufacturer's part number).

The government's theory was that DoD—like others who buy commercial items—will have no need for technical data. Initially, the barriers (legal, economic, and technical) to

competitive procurement will likely be very limited almost by definition—the items or assemblies are originally purchased competitively as a commercial item. However, over the long term, the effects of individual barriers to competitive procurement may change. For example, if the number of commercial sources for a particular market declines, one or more of the following may apply:

- **Legal barriers.** Competitive build-to-print options may be limited due to the lack of data rights or the absence of a detailed TDP.

- **Economic barriers.** The cost to develop and use performance specifications, or to acquire data rights, may be excessive.

- **Technical barriers.** Any of the technical factors discussed in Section A.2 could conceivably come into play, depending on a variety of circumstances. For example, a performance specification at a part level may not be adequate if additional requirements were present at the *system* or *assembly level* (and by coincidence reflected in the original part), yet not included in the performance specification details at the *part level.* Additionally, the lack of an adequate TDP may limit the flexibility for the operating and support communities to alter support, maintenance, and repair strategies over the lifecycle of the item or assembly.

A number of viable options are available to address potential long-term legal, economic, and technical barriers to post-production procurement of commercial items, among them:

- Using long-term sustaining engineering partnerships between DoD and weapon system primes to address inevitable out-year problems.

- Instituting reverse engineering studies and analysis on a case-by-case basis to identify current F3I (form, fit, function, interface) alternatives.

- Adopting open system architecture approaches that will be more likely to have alternative F3I solutions meeting future needs with commercial off-the-shelf (COTS) products.

While many appropriate options will be driven by case-specific post-production needs in the future, actual trade-off management options may be limited if the desired information and/or contractual commitments to access data were not arranged at the time of initial product acquisition.

The commitment to place *emphasis* and *priority* on competitive purchases of commercial items should not preempt sound, long-term maintenance strategy planning. Instead, acquisition reform strategies should include tradeoff analyses that give an appropriate balance of competitive acquisition tools to acquisition managers for both current acquisition and future post-production needs.

A.3.4 Performance-Based Acquisition

A.3.4.1 Summary

Many of the people interviewed implied that this area represents the essence of the defense acquisition reform, and that these changes may have the most significant effect on future TDPs. *While performance specifications are not new, the emphasis given to them represents a significant departure from past defense acquisition policies and practices.*

In the IDA assessment that follows this summary material, we provide a detailed discussion of the new defense acquisition strategy, giving priority to performance specifications. But first we include excerpts from the four major documents that illustrate, in terms of guidance and implementation, new DoD policy and practice changes.

Perry, William. 29 June 1994. *Memorandum: Specifications & Standards – A New Way of Doing Business*. Washington, DC: Office of the Secretary of Defense. [Perry 1994]

> **Military specifications and standards.** Performance specifications shall be used when purchasing new systems, major modifications, upgrades to current systems, and non-developmental and commercial items, for programs in any acquisition category. If it is not practicable to use a performance specification, a non-Government standard shall be used. Since there will be cases when military specifications are needed to define an exact design solution because there is no acceptable non-Governmental standard or because the use of a performance specification or non-Government standard is not cost effective, the use of military specifications and standards is authorized as a last resort, with an appropriate waiver.
>
> **Configuration control.** To the extent practicable, the Government should maintain configuration control of the functional and performance requirements only, giving contractors responsibility for the detailed design.

Department of Defense. March 15, 1996. *DOD Directive 5000.1, Defense Acquisition.* [DODD 5000.1]

> **Performance specifications.** In solicitations and contracts, standard management approaches or manufacturing processes shall not be required. Performance specifications shall be used when purchasing new systems, major modifications, and commercial and nondevelopmental items. Performance specifications include DoD performance specifications, commercial item descriptions, and performance-based non-Government standards. If it is not practicable to use a performance specification, a non-Government standard shall be used. There may be cases when military specifications are needed to define an exact design solution because there is no acceptable non-Government standard or because the use of a performance specification or non-Government standard is not cost-effective, not practical, or does not meet the user's needs. In these cases, the use of military specifications and standards is authorized as a last resort, with an appropriate waiver or exception from the MDA.

Department of Defense. March 23, 1998. *DOD Instruction 5000.2-R, Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information Systems Acquisition Programs.* [DODI 1998]

Best practices. The PM shall avoid imposing Government-unique requirements that significantly increase industry compliance costs. Examples of practices designed to accomplish this direction include: IPPD performance-based specifications, management goals, reporting and incentives; open systems approach (that emphasizes commercially supported practices, products, specifications, and standards); replacement of Government-unique management and manufacturing systems with common, facility-wide systems; realistic cost estimates and cost objectives, adequate competition among viable offerors; best value evaluation and award criteria; use of past performance in source selection, results of software capability evaluations; Government-industry partnerships; and the use of pilot programs to explore innovative practices. The use of best practices shall be addressed at each milestone review.

SD-15, Defense Standardization Program: Performance Specification Guide. June 29, 1995. Falls Church VA: Office of the Assistant Secretary of Defense (Economic Security), Standardization Program Division. [SD 1995]

Background ...current DoD policy is to move to greater use of performance and commercial specifications and standards. This will increase DOD's access to commercial state-of-the-art technology. As a result, DOD will gain direct access to the existing commercial industrial base for defense applications [SD 1995, p. 3].

Performance specifications. Performance specifications leave out unnecessary "how to" or detail and give the manufacturer latitude to determine how to best meet stated needs. The word "unnecessary" is emphasized because some detail requirements are necessary in a performance specification. Almost always the need for detail is generated by interface requirements [SD 1995, p. 5].

Requirement. Any condition, characteristic, or capability that must be achieved and is essential to the end item's ability to perform its mission in the environment in which it must operate is a requirement. Requirements must be verifiable [SD 1995, p. 9].

Performance requirements. Performance requirements should describe interfaces in sufficient detail to allow interchangeability with parts of different design. Interface considerations should be addressed carefully when using performance specifications. For example, the specification must enumerate the interface requirements necessary to allow maintenance at the appropriate level, but it must not impose a design solution beyond that necessary to ensure a proper interface [SD 1995, p. 10].

Reprocurement. When a performance-based specification results in a contract award, competitive reprocurement will follow the same process. The technical data package or drawing (if there is one) resulting from the previous buy will be provided "for information only." The performance specification remains the baseline....Changes which affect logistics support must be identified and carefully weighted. Interchangeability to the spare part level may be required to ensure that logistics support is not critically degraded [SD 1995, p. 13].

Request for Proposal. The RFP should reference the current specification and technical data package (TDP) for the item, if one is available, but state explicitly that the TDP is provided for information only....A performance specification approach to acquisition represents a shift from the "build-to-print" environment of the past. It requires the user to identify essential requirements for the item and areas in which improvements would be desirable [SD 1995, p. 14].

Reprocurement. The performance-based acquisition does not encourage the continuing reprocurement of the same item. It expects the Government to capitalize on the technical expertise and ability of the industrial community in order to procure products at continually improving levels of performance and reliability [SD 1995, p. 14].

Level of specification. One of the largest areas of uncertainty on the part of specification writers revolves around the question "How low should I go?" in the development of performance specifications. In other words, "[T]o what level do I control the hardware?" Two answers are useful. First, the writer should not specify below the lowest replaceable unit. It makes little sense to specify below the level at which we will remove and replace parts. Second, the writer should specify to the level necessary to ensure that the item will meet the user's need and can be supported cost efficiently [SD 1995, p. 25].

Form, fit requirements. ...similar for both design and performance specifications. Form, fit requirements are acceptable to ensure interoperability and interchangeability [SD 1995, p. 32].

Additional data. Often requires more data from the contractor since the TDP may be needed as a baseline for reprocurements. Contractor has prepared the TDP [SD 1995, p. 35].

A.3.4.2 IDA Assessment

In this section we address the effects of acquisition reform on competitive procurement using TDPs, specifically in the post-production periods. We make no attempt to evaluate the benefits of acquisition reform to defense programs in development or in early transition to production.

While acquisition reform is well underway, it will take several years to quantify actual benefits. Nevertheless, we agree with many other commentators on this subject, that overall, this initiative will prove beneficial to DoD. However, as with any strategy or approach there will be consequences—both positive and negative. In the context of this study, we have attempted to assess the effects of these changes relative to TDPs and any resulting barriers to their use in competitive procurement. Because some conditions we discuss may not yet exist, this particular assessment will be based on historical similarities and collected comments by knowledgeable participants in the field of the competitive use of TDPs. Each independent assessment is presented relative to the three barriers—legal, economic, technical—discussed in Section A.2.

A.3.4.2.1 IDA Assessment – Legal Barriers

The effects of acquisition reform should generally be positive with relatively minor effect on the legal barriers because acquisition using performance-based specifications was one of the circumventing strategy alternatives already acknowledged. However, suitable performance specifications may not always be available for specific items. This situation is most likely for items below a major assembly level where verifiable performance requirements and interface control documents have not been prepared.

We have identified potential concerns—largely hypothetical at this time. However, we feel that these concerns will likely need resolution in the future.

Liability assignment. A new legal issue that may become a barrier is, who is liable/responsible (government or contractor) for certifying compliance of performance specifications when change control authority does not resides at a DoD organization (e.g., the authority resides at one or more contractors somewhere within the industrial base)?

Mismatch of skill needs. Will the lack of detailed build-to-print TDPs limit competition, resulting in contract awards to manufacturing enterprises (possibly small businesses) capable of economically building to a print—but less skilled in producing a verifiable design to performance specification? Will this condition run counter to the intents of CICA, FASA, and FARA?

Proliferation of limited rights. Will a contractor who makes detail design changes to a product (and ultimately the TDPs) be able to claim to limited rights in data for the new configuration product? A potential situation where this might occur is under performance-based acquisition where product design ownership and configuration control for detailed design resides at one or more contractors. This situation would typically exist at one or more levels of assembly below the DoD configuration-controlled performance requirements (e.g., form, fit, function specifications).

A.3.4.2.2 IDA Assessment – Economic Barriers

The nature of economic barriers should remain essentially unchanged. That is, the main determinant for deciding between sole-source or competitive contract award from solely an economic perspective will be the relative difference between the following:

- The costs for establishing competition.
- The potential cost savings and other related benefits that may be derived from competition.

However, the flexibility to change from one strategy to another late in production of the system, or after system production has ceased (e.g., post-production), may be limited by the nature of the strategy last used to acquire parts or services. The following list is intended to illustrate a sample of possible case scenarios:

- Part or artifact (supplier unknown or no longer available, no drawing, and no performance specification)
- Commercial supplier part number (P/N) (sole-source, no drawing, no performance specification)
- Commercial supplier P/N (cross-reference to other supplier P/Ns, no drawing, no performance specification)
- Defense supplier P/N (sole-source, no drawing, no performance specification)
- Multiple defense suppliers by NSN (national stock number) (manufacturers that have been qualified and/or certified as capable to supply specific items)
- Detailed TDP (build-to-print, limited rights)
- Detailed TDP (based on performance specifications)
- Detailed TDP (build-to-print, unlimited rights in data)

Clearly, there will exist programmatic cost, schedule, and performance risk variations for each unique strategy based on one of above examples. Actual achievable benefits will be situation dependent—for example, a function of the adequacy of a TDP in hand or available, or the TDP that might have been available had a different strategy been in place during an earlier acquisition.

A.3.4.2.3 IDA Assessment – Technical Barriers

The following presents the assessment of potential effects, first on the acquisition of adequate TDPs and then on effective transmission of reprocurement technical requirements. This order is consistent with the discussion of technical barriers covered previously, and addresses each of the major influencing factors.

Acquisition of Inadequate TDPs

Know-how not captured. Performance-based acquisition could act like a doubled-edged sword. For example, a supplier would not be restricted to unavailable "know-how" details of a specific design solution. However, some additional reverse engineering or redesign would likely be needed in specific circumstances where the "know-how" was missing.

Latent errors. Presumably, latent errors in detailed design drawings will not present a difficulty for performance-based acquisitions because contractual requirements are defined at the performance level. However, there is no assurance that latent errors will not be present at a performance specification level.

Checking and verification errors. Potential problems may be less severe for a build-to-print TDP than for a performance-based acquisition. In the case of performance-based acquisition, it may represent a more significant challenge to check and verify error-free performance specifications for specific part and assembly levels that previously were not prepared.

Process details not captured. Performance-based acquisition could act like a doubled-edged sword. For example, a supplier would not be restricted to unavailable process details of a specific manufacturing or design solution. However, some additional reverse engineering or redesign would likely be needed in specific circumstances where the process details were missing.

Lagging configuration changes. Problems may or may not be aggregated at a performance specification level. This will tend to be situation dependent.

Incomplete design disclosure. This will not be an issue under performance-based acquisition strategies. However, very complex assemblies may be costly to redesign to a performance specification.

Inclusion of proprietary data or markings. To the extent that existing drawings and TDP will be provided solely as information along with a performance specification, the effects of acquisition reform will not likely be an issue. However, data provided will need to be free of rights-in-data restrictions.

Limited experience preparing reprocurement TDPs. The effects of acquisition reform will not likely be an issue for this factor.

Effective Transmission of Reprocurement Technical Requirements

Contractor capabilities not matched to TDP requirements. The performance-based acquisition approach may present greater programmatic risks by adding an additional challenge to successfully match both design and manufacturing capabilities to a specific performance-based design need.

Potential of underbids and buy-ins. The full gamut of issues and problems that exist today likely will exist in the future, independent of the acquisition strategy used.

Need for a diversified pool of engineering talent. Under performance-based acquisition strategies, there will likely be an increased need for a diversified pool of engineering talent. This condition will tend to be driven by the need to recreate new performance-based design solutions. The need to select from suppliers with greater ranges of engineering talent may exclude some very economical and highly qualified manufacturing enterprises that specialize in built-to-print jobs.

Conditions of use not as initially intended. The full gamut of issues and problems that exist today likely will exist in the future, regardless of the acquisition strategy used.

A.3.5 Technical Advances in CAx

A.3.5.1 Summary

The broad application of computers to problems of design, manufacturing and engineering analysis is relatively recent. The computer revolution of the past three decades has played a dominant role in advancing automated and assisted design, manufacturing and engineering capabilities, specifically related to computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE). The following subsections track this growth from several perspectives:

- Declining cost of CAD.
- Direct linkage to manufacturing.
- Interactive graphics and modeling capabilities.
- Data sharing and networks.

Declining CAD Prices

The use of computer graphics for engineering design began in the styling studios of the automobile industry little more than thirty years ago [Wysack 1996, p. 3]. However, the computer-assisted capabilities were not wide spread in the 1970s and early 1980s, principally because of the high costs. A major obstacle to the widespread use of CAD systems in the early 1980s was the high costs of graphic workstations, typically costing $50,000 to $100,000 each.

Consequently, to be cost effective, these CAD systems needed to help the designer to be more productive. By the early 1990s, functionally equivalent personal computer (PC) based CAD systems were available in the $12,000 range [Wysack 1996, p. 98]. Now there is even greater computing power at less cost, coupled with relatively low cost, commercially available, mid-range CAD systems. A recent article appearing in *Computer Graphics World* presents results of a benchmark study of five leading solid modeling programs priced below $6,500. All five programs were viewed as serious contenders in the mechanical CAD arena, possessing capabilities that would have cost $18,000 and up only 18 months ago in similar software packages [CGW JAN 1997, p. 29].

Another review in *Computer Aided Design Report* [CAD Jun 97] found that

> [p]rices of mechanical CAD systems have fallen 16 percent since 1995, according to a study by Technicom, Inc. The study compared prices by soliciting bids on 14 systems in five and 11-seat configurations. On a five-year basis (which includes software maintenance charges), the three most costly were CATIA, Pro/Engineer, and I-DEAS, while the three least expensive were Microstation Modeler, HP's SolidDesigner, and Intergraph's Solid Edge.

Direct Linkage to Manufacturing

The origins of CAM began in the 1950s. The first prototype numerical-control (NC) machine tool was introduced at the Massachusetts Institute of Technology in 1952. This development was followed in 1954 by a symbolic language called APT (automatically programmed tool) and the first commercially available NC machine tools in 1957 [Kalpakjian 1995, pp. 1122, 1130]. With the growth of computer technologies and the introduction of CAD systems, the logical use of computers and computer technology to assist in all phases of manufacturing a product expanded.

Today, databases developed in CAD are stored and processed further by CAM systems into instructions for operating and controlling production machinery, manufacturing processes, material-handling equipment, and automated testing and quality inspection equipment [Kalpakjian 1995, p. 1181].

Interactive Graphics and Modeling Capabilities

The advent of interactive computer graphics dates back to the early 1960s with the development work of Ivan Sutherland at the Massachusetts Institute of Technology. Because of high costs, widespread use did not occur until the mid-1970s and early 1980s. The display of complex objects before this time was both too slow and too costly due to the computational intensive operations required (e.g., data transformations of an object from a three-dimensional spatial coordinate system to the desired two-dimensional display screen rendering, with hidden lines and hidden surfaces eliminated or clipped) [Hodson 1992].

From the late 1970s through 1988, techniques were all basically the same for modeling objects as solids (solid modeling), using various combinations of geometric entities. La Course tracks the beginnings of solid modeling in his *Handbook of Solid Modeling*:

> In the late 1980's, the term parametric solid modeling was applied to a product from Parametric Technology Corporation (PTC), which produced the first commercial example of what we call today parametric/relational (or dimensional-driven) solid modeling. By January 1994, there were at least seven significant dimension-driven and/or variational solid modeling systems in the marketplace, with more appearing every few months [La Course 1995, pp. 8.1–8.2].

La Course goes on to point that this new dimensional-driven approach makes use of variables and constraints in the solid model generation and modification, and governs the operations by mathematical and topological relationships.

Solid models contain not only information about the shape of an object; they also provide an analytical model of the volume embodied by these shapes.

> By employing spatially "complete" models, solid modeling (SM) systems are able to apply computer power directly to the design of parts and assemblies rather than to lower-level details such as drawings [La Course 1995, p. 4.1].

Consequently, solid models provide great insight for engineering analyses such as mass properties, interference and assembly modeling, and kinematics.

Data Sharing and Networks

In its CAD/CAM Roundtable, the Society of Manufacturing Engineers (SME) recently observed the following:

> Recent trends in network utilization and sharing of information are driving objectives that the CAD/CAM community has had for years. Specifically, interoperability and common core functionality are in the forefront of every CAD/CAM vendor's product development activities. This is now making the integration of applications possible through advanced interoperability of "best in class" software for MRP (Manufacturing Resources Planning), PDM (Product Data Management), and CAD/CAM to name a few [SME May 1997, p. 9].

Expectations for the Future

SME also observed that "there is a definite trend toward commercially available software as opposed to internally developed [SME May 1997, p. 9]. In the CAD/CAM Roundtable study, SME drew two conclusions:

> The increased use of distributed work across networks demands better interoperability between CAD/CAM systems and more standardization....We are on the threshold of a quantum increase in the speed and interoperability of CAD/CAM applications as operating systems take advantage of hardware developments and core software becomes optimized [SME May 1997, p. 9].

Jim Medlock [1997], Chairman and CEO of Intergraph Corp, characterized his view of what will represent the major CAx drivers for the next decade:

- Internet (and all Web-related technologies).
- Commercial computer operating systems.
- Commercial computer architectures.
- Plug-and-play software.
- Object data bases.

While there are clearly other drivers for CAx (e.g., integrated circuits cost and performance curves for memories and processors; commercial demands for capabilities in other markets), other speakers and attendees voiced wide agreement with Medlock's remarks, providing us with a level of confidence that these drivers will have at least a near-term influence on the CAx industry.

A.3.5.2 IDA Assessment

Recent advances in CAx technologies are having a broad and direct influence on mechanical design and manufacturing. For example:

- The number of CAx seats (installed CAx systems) for mechanical design and manufacturing is increasing in large measure because of the combined benefits of declining costs and increasing computer-assisted capabilities.

- Distinctions between high-and mid-range systems are shrinking. This change is putting very powerful design tools, previously reserved for the costly design of a few complex assemblies, in the hands of nearly all designers.

- The broad range of CAx COTS integrated systems and third-party tool sets are providing a wide range of capabilities, including rapid prototyping; photo-realistic rendering; direct CAM interfaces for milling, machining, or sheet-metal; weight, balance, and moment of inertial calculations; kinematics analyses; and finite element analysis tool interfaces.

- Initial design and modeling times are being reduced by an order of magnitude (if months, to weeks or days; if days, to hours). For example, in conjunction with the RAMP program, more than a thousand mechanical TDPs were re-drawn from legacy data formats, and required an average time of only 2.5 hours for a designer using modern CAD tools to re-design the item.

The potential effects of these technology advances on the competitive use of TDPs are assessed in the following sections.

A.3.5.2.1 IDA Assessment – Legal Barriers

The effects of CAx technology advances on existing legal barriers should be relatively minor. However, an additional legal issue, which is a direct result of the CAx technology advancement, may exist in the future: *New requirements and legal commitments to accurately store and retrieve product data over time.* Because of the significance of "data storage and retrieval" to this study, and because this area tends to have an effect on all three barriers to competitive procurement using TDPs, it will be assessed independently in Section A.3.6 on page A–28.

A.3.5.2.2 IDA Assessment – Economic Barriers

Profiles of design cost curves are shifting downwards, and thus the location of break-even points are changing. Modern CAx systems (even the mid-range varieties) provide very high performance design and analysis capabilities, including the following:

- Reduced design time.

- Improved design quality through the use of integrated design analysis tools.
- Reduced performance validation time with rapid prototyping tools.
- Decreased design-to-manufacturing transition time with integrated CAD to CAM linkages.

Actual economic tradeoffs will be situation dependent. However, under all circumstances it will become more economical—as compared to a few years ago—to produce a new TDP by redrawing from legacy data and/or redesigning from performance specifications.

A.3.5.2.3 IDA Assessment – Technical Barriers

While the time to design and the quality of the designed product have clearly moved in a positive direction as a result of CAx advances, the effects on technical barriers to competitive procurement are mixed—both positive and negative.

Acquisition of Inadequate TDPs

Know-how not captured. Even with the all the CAx technology advances, engineering design rationale and intent are not automatically captured. During a visit to the Manufacturing Engineering Laboratory at the Manufacturing Systems Integration Division of National Institute of Standards and Technology (NIST), we were told that "no commercially available design intent tools exist." Others interviewed at NIST, PDES, Inc., and the M/CAD Expo 97 stated that the only approach known to work is paper (e.g., the green engineering workbooks).

But at the same time new CAx capabilities will make it easier to perform design evaluations using integrated analysis capabilities such as those provided by the finite element analysis tools. However, the existence of these new capabilities may also represent a double-edged sword: these new design analysis tools will be used by engineers to optimize future designs around critical operating and performance requirements. One consequence may be increased risks (in terms of cost, schedule, and performance) of successfully matching the form, fit, and function of existing items for which special design attributes were carefully optimized. Furthermore, the criteria used by the engineering team, and verified through careful test and analysis, are not captured by the CAx systems.

Latent errors. The new CAx technologies based on solid modeling are more likely than the older technologies to avoid many of the past sources of latent errors (e.g., dimensional discrepancies across multiple views, dimensional discrepancies across multiple assemblies, topological discrepancies). These improvements are the result of the computer program keeping track of what the entire item looks like, and automatically creating desired views from this single computer model of the item. Consequently, the dimensioning is totally consistent and dependent on the viewing direction desired. Furthermore, a true solid model will not permit the designer to create an object that is not topologically correct from a mathematical perspective. In addition, re-drawing a mechanical part from leg-

acy data using new solid modelers is not only much faster than was practical in the recent past, the solid modelers also tend to help identify many of the latent errors contained in the original.

Checking and verification errors. Some aspects of checking and verifying that TDPs are error-free will improve with new CAx capabilities, while other aspects may degrade. For example:

> Firms that wouldn't think of issuing a drawing or specification without proper checking will do so with a solid model. Tools for marking up solids are not good. Sometimes release engineers can't make changes to models because they aren't expert with the CAD system, yet these engineers have no easy way to convey to the model creator what changes are needed. Parts need to be checked in assemblies for proper fit. Mating relationships need to be defined, not just "eyeballed." Feature definitions, variable definitions, datum planes, and relationships between variables must be checked to assure that each model properly captures the intent of the designer. Until all designers, engineers, and checkers can afford their own CAD seats and until CAD systems become easier to use, checking will remain a problem [CAD Mar 1997, p. 3].

However, with direct linkage from CAD to CAM, intermediate steps previously required to create NC instructions for automated manufacturing equipment can be eliminated. Thus, manufactured parts are more likely to reflect the features defined by the CAx solid model.

Process details not captured. Typically, manufacturing process details will not be captured as part of the TDP by modern CAx systems. However, there are some exceptions where applied knowledge-based engineering rules have been embedded in the system software. Typically, these exceptions are cases of domain-specific applications, and often the defined rules are dedicated to a specific model or version of manufacturing equipment or even a specific machine.

While not in wide spread use at this time, add-on capabilities are available from several CAx suppliers that permit users to define their own design and process rules (typically domain specific) that automatically transfer to a part being generated. To the extent that these rules are codified and the logic of when and how they are applied is known, some of the process details may then be captured. This type of information is not typical of the information included in a TDP. The data tend to be proprietary in nature and are often domain specific, based on unique manufacturing capabilities at a contractor's facility.

Lagging configuration changes. New automated tools may help to eliminate some of the past problems, provided these new capabilities are used. Because of significance of "configuration tracking" to this study, and because this area tends to have an effect of all three barriers to competitive procurement using TDPs, it will be assessed independently in Section A.3.7 on page A–33.

Incomplete design disclosure. It is unlikely that the new capabilities associated with advanced technology CAx systems will significantly alter the frequency of this problem in the future.

Inclusion of proprietary data or markings. It is unlikely that the new capabilities associated with advanced technology CAx systems will significantly alter the frequency of this problem in the future. If a contractor is inclined to use proprietary components where non-proprietary components would serve equally as well, the advanced CAx capabilities will facilitate this practice. However, if a contractor is inclined to use standard, commercially available and/or non-proprietary components, the advanced CAx would serve equally as well to facilitate this practice.

Limited experience preparing reprocurement TDPs. The improved CAD-to-CAM linkage will tend to enhance the manufacturing skills of a contractor who is distinctly "research and development" oriented. At the same time, the powerful nature of the integrated analysis tools in the new CAx systems will tend to enhance the design skills of a contractor who is distinctly "production" oriented.

Ineffective Transmission of Reprocurement Technical Requirements

Contractor capabilities not matched to TDP requirements. While matching the government's requirements to a supplier's capabilities will likely remain a challenge, new CAx capabilities may help to level the playing field by placing powerful design and analysis tools in the hands of all engineers.

Potential of underbids and buy-ins. If a contractor is inclined to want to find fault with a TDP, the new CAx capabilities will make his task easier. However, on the positive side, benefits of these new capabilities should help to mitigate a contractor's programmatic risks. New CAx technologies may help contractors to bring in their job on time, under cost, and at or above performance thresholds.

Need for a diversified pool of engineering talent. New CAx technologies will mitigate some problems by supplementing the available pool of engineering talent with advanced capabilities such as finite element analyses tools which had previously been reserved for a limited set of very costly or critical design activities. By all indications, the range and breadth of integrated design and analysis tools should continue to grow and, simultaneously, the cost for these features should decline.

Conditions of use not as initially intended. It is unlikely that the new capabilities associated with advanced technology CAx systems will significantly alter the frequency of this problem in the future.

A.3.6 Technical Data Storage and Retrieval Approaches

A.3.6.1 Summary

This section addresses the changes to technical data storage and retrieval approaches in conjunction with transition from paper-based product data to a range of formats for electronic and digital product data. Included is a discussion of storage and retrieval problems and challenges, with special emphasis on data exchange limitations.

Background

The Services and DoD agencies manage millions of engineering drawing images. As one example, the Air Force reported managing over 42 million drawing images in various formats, with almost 32 million of these drawing images currently inactive [AF 1996]. The other Services have similar situations.

Many of the inactive engineering drawing images held by the Services are paper based; however, most are retained on aperture cards (old IBM punch card formats with 35-mm photographic negatives attached). Of the active engineering drawing images held by the Services, most are in an electronic digital format stored in Engineering Data Computer Assisted Retrieval System (EDCARS), Digital Storage and Retrieval of Engineering Data System (DSREDS), or Joint Engineering Data Management Information and Control System (JEDMICS). During the 1980s, the Air Force and Army jointly developed systems to store raster scanned digital images of engineering drawings. The Air Force named its system EDCARS and the Army named its system DSREDS. A few years later, the Navy and the Defense Logistics Agency jointly developed a newer electronic data repository system named JEDMICS. In November 1991, JEDMICS was designated as the DoD standard system, and the transition from EDCARS and DSREDS to JEDMICS began.

The guidelines for JEDMICS data delivery requirements [JEDMICS 96] noted the following:

> While intelligent data formats can be stored on JEDMICS, such formats are not completely supported by the initially issued hardware and software capabilities. Intelligent data formats can be retrieved and viewed with add-on viewers if the JEDMICS field agency chooses to make such enhancements. However, the indexing requirements for intelligent data storage is not supported by the JEDMICS data base at this time....The JEDMICS Program Management Office has asked South Carolina Research Agency (SCRA) to determine the enhancements required to JEDMICS to permit any format of data to be stored, accessed, and retrieved. The product of this six-month effort will be a data model detailing the enhancements to the JEDMICS system. These recommendations will be implemented in future releases of the JEDMICS software. These enhancements will permit storage and retrieval of data such as native CAD files, neutral CAD files, page description language (PDL) and portable document format (PDF) files.

Electronic and Digital Data Formats

In the context of product definition data, the American Society of Mechanical Engineers defines digital data as the following:

> Data created and stored on a computer system which employs a display on which the user and the computer interact to create entities for producing layouts, drawings, numerical control tapes, or other engineering data [ASME 1992].

A variety of unique data formats exist, and the proliferation of formats parallel the performance growth and introduction of new computer hardware and software systems upon which they are hosted.

The proliferation of native CAD formats is growing, with many formats unique to a proprietary tool and/or software version. Two major factors have contributed to the format proliferation: (1) the generational improvements in CAD capabilities, and (2) the very competitive markets. Today's CAD systems have progressed from first-generation drawings, to second-generation wireframes, to third-generation surfaces, and currently to fourth-generation solids. Our visit to the South Carolina Research Authority garnered the many comments about this continuing proliferation, among them:

> CAx systems have very competitive markets; there exist multiple vendors in each of the mid- and high-performance CAx markets; and no single CAx system nor company is likely to dominate the markets within the next five years (and probably longer) [SCRA 1997].

The Initial Graphics Exchange Specification (IGES), Version 1.0, was published in 1980. IGES provided a neutral data format for describing and exchanging product design and manufacturing information, thus reducing the need for direct translators between every CAx system. A survey conducted by the CAD/CAM Data Exchange Working Group of Automotive Industry Action Group in 1989 inquired as to what data formats were "required to do business" and which were required for "in-house capabilities." IGES was required by 61% of the 96 respondents, and used for in-house capability by 71%. The next closest formats identified by the respondents were 15% and 24%, respectively. [La Course 1995]

The inadequacies of data translation methods prompted a parallel initiative to IGES in 1984 to develop a broad set of international data exchange standards. ISO 10303, a new standard of product data exchange, has emerged as the Standard for the Exchange of Product Data (STEP) from the International Organization for Standardization [La Course 1995].

However, difficulties persist as indicated by this passage from a General Motors report [GM 1997]:

> Data sharing and exchange among these proprietary tools requires difficult data translation between these systems. This results in inaccuracies and loss of data, resulting in costly rework and redundant data creation.

Data Exchange Problems and Limitations

Our interviews and literature searches showed awareness of remaining problems and progress towards resolving them in regards to data exchange. South Carolina Research Authority personnel observed that

> data exchange capabilities have lagged (and will likely continue to lag) the rapidly advancing capabilities of CAx tools.... While lagging at the cutting edge of technology, new abilities to share, manage, and exchange data between widely different CAx architectures and data formats are vastly more capable than just a few years ago [SCRA 1997].

The expectation of long-term benefits are illustrated by the wide adoption of STEP by designers of large scale systems:

> STEP has been adopted by virtually all of the aerospace and automotive original equipment manufactures in the world through signed memorandums of understandings [SME May 1997].

However, there is great room for improvement:

> None of the data translation methods effectively exchange parametric relationships between CAx data models, and likely will not have this capability in the near term [SCRA 1997].

In addition, the representatives of the Manufacturing Engineering Laboratory at NIST indicated that short of exchanging data between like machines (running the same software tools and using a database of the native CAx format), there is no neutral or common exchange format that assures error-free and/or non-data loss transfer. And relying on native CAx database formats will not assure data will be preserved when the hardware and software versions change (i.e., not always downward compatible).

NIST representatives indicated that STEP is the "only game in town which has a viable strategy to get there some day." How long it will take, and the degree of success in keeping up with technology advances, will be determined by market forces and demands. The following summarizes the comments and examples presented by NIST personnel.

Lost data and flexibility. Some CAD design flexibility and design information are lost nearly every time CAD data is changed from its native database format to a neutral (IGES), common (STEP), or *de facto* (e.g., DXF) data base format. For example, converting from a Pro/Engineer database format to STEP will permit very good solid-model form factor data exchange; however, once exchanged, the Pro/Engineer CAD operating from the STEP database loses some of its original flexibility to modify the design.

Costs of data exchange. For some designs it is still quicker and cheaper to re-draw than to translate the CAD database. Depending on how extensive design changes may be, the lost CAD flexibility and lost relational dimensioning capabilities may force the design to be re-drawn if original CAD data are not available.

Boeing "cave story." Boeing apparently maintains copies of its legacy CAD/CAM databases and tool software and hardware in a temperature- and humidity-controlled vault or cave. Boeing recopies the software every four years to assure the magnetic tape medium does not deteriorate.

Tolerancing difficulties. None of the CAD systems does a very good job handling tolerances. The NIST representatives cautioned that we not confuse interference analysis and "fly-through" capabilities with tolerancing.[1] Today's systems rely on making a 2D rendering (paper or screen) of the object, and adding in the tolerances. Some good application protocols or CAE tools exist that assist in conducting tolerance stack-up analyses; however, there are no standards for this activity at this time.

Integrated Data Environment Initiative

In 1994, the Continuous Acquisition and Lifecycle Support (CALS) program prepared a vision statement calling for the deployment of an Integrated Data Environment (IDE) concept. Under the concept of operations, "defense contractors, subcontractors, and suppliers deliver product information in place in accordance with industry development application packages [IDE 96]." Program offices, depots, and Service field activities may then access the information when needed.

If widely implemented, this concept may help eliminate redundant data storage and maintenance at multiple locations (e.g., service depots, program offices, contractor's and sub-contractor's facilities). In theory, data will be retained by the contractor in the contractor's preferred data formats, and the Services will obtain data if and only if needed. Variations of this experiment are being applied widely across the Services, with the near-term benefits of reduced initial data costs for engineering documentation and technical data packages.

A.3.6.2 IDA Assessment

The influence of technical data storage and retrieval capabilities on competitive procurement will tend to be situation dependent. However, any adverse effect on competitive procurement for mechanical design applications will likely be slight for the following reasons:

- Electronic storage and retrieval of data should help eliminate problems associated with lost data (i.e., aperture cards or paper drawings lost or put back in wrong location).

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[1] Fly-through capabilities represent the ability of a CAD system to display a 3D model in relative space, giving a perspective to the user viewing the display terminal that he/she is moving around or even through this 3D model.

- Most of today's mechanical CAD systems provide translation to a neutral data format such as IGES or STEP.

- Modern solid modeling CAD systems have significantly reduced the time and risks of capturing product definition data from legacy drawings (the example given by the South Carolina Research Authority was an average capture time of only 2.5 hours that was demonstrated on more than a thousand TDPs for mechanical-designed items [SCRA 1997]).

The following sections provide additional insight from the perspective of technical data storage and retrieval approaches on the three barriers to competitive procurement.

A.3.6.2.1 IDA Assessment – Legal Barriers

Immediate effects should be minimal because technical data being stored in defense data repositories are raster-scanned images (JEDMICS, EDCARS, and DSREDS compatible) from which drawing image copies may be provided to all potential bidders in existing acceptable transmission formats (e.g., paper, digital, aperture cards).

However, any procurements that depend on data formats that are not fully available to all potential bidders may pose a legal barrier in the future by effectively restricting "full and open competition" to bidders with specialized capabilities—thereby running counter to the intents of CICA, FASA, and FARA. In addition, DoD agencies may be confronted by new challenges when attempting to identify specific data stored in contractor repositories that are restricted from release due to limited rights.

A.3.6.2.2 IDA Assessment – Economic Barriers

We agree that the relative costs of one data storage and retrieval strategy over another may be substantial. However, we were unable to identify good approaches for realistically comparing the costs of different strategies with any certainty.

A.3.6.2.3 IDA Assessment – Technical Barriers

Effects of storage and retrieval on the adequacy of the TDPs. No significant changes associated with the frequency of latent errors should be observed as a result of the transition from paper to raster-scanned data. However, data that is exchanged between different CAx systems may contribute to existing errors within the TDPs.

Effects of storage and retrieval on the effective transmission of reprocurement technical requirements. The effects may be mixed (i.e., both positive and negative). For example, automated capabilities may improve the accuracy of data transferred, may increase data exchange efficiencies, and may speed up the contract award process. The data exchange difficulties previously addressed may be used by contractors to justify additional expenses.

A.3.7 Configuration Control and Management

A.3.7.1 Summary

The main thrust of acquisition reform from a configuration management perspective is to maximize the use of performance-based specifications; to focus on process control, in lieu of inspection; and to integrate military and commercial development and manufacturing [Ucchino 1995].

Recent changes to DoD configuration management policy have resulted in the phasing out of MIL-STD-973, Military Standard Configuration Management, and the introduction of three new documents to present current policy and guidance:

- Electronic Industries Association (EIA) Standard 649, National Consensus Standard for Configuration Management, 10 August 1995.
- MIL-STD-2549, Configuration Management Data Interface, 30 June 1997.
- MIL-HDBK-61 (Draft), Military Handbook Configuration Management Guidance, 31 March 1997.

The configuration management principles and practices presented in these documents are from an enterprise perspective, and these documents acknowledge that each enterprise must assign responsibilities in accordance with its own management policy in such a way as to accommodate the stated configuration management requirements. The configuration control and management activities, as outlined in these documents, have evolved to be consistent with new acquisition strategies.

Acquisition reform has significantly changed the environment from one dominated by DoD-imposed management requirements (and the ubiquitous detailed military specifications and standards) to acquisition strategies based on performance specifications and the use of industry standards and methods to the greatest extent practicable. As a direct consequence, defense acquisition and support communities have entered a new era, with the use of the following technologies and practices:

- Shared-use technical data bases.
- Distributed design control and ownership.
- Electronic access to information.
- Less detailed and more performance-based requirements at logical intra-system interfaces.

However, while the implementation perspective for configuration management has changed, basic requirements are essentially unchanged. This is illustrated by DoD Regulation 5000.2-R requiring the following:

> A configuration management process to control the system products, processes and related documentation. The configuration management effort includes identifying, documenting and verifying the functional and physical characteristics of an item; recording the configuration of an item; and controlling changes to a item and its documentation. It shall provide a complete audit trail of decisions and design modifications [DODI 5000.2R].

There is more than one way to achieve these requirements, but the focus on implementation is of interest here. Thus it is necessary we address the performance requirements and characteristics of configuration management processes to support lifecycle needs for the following:

- Products developed, acquired, and supported to performance-based specifications.
- Products incorporating COTS products and NDIs.
- Products developed, acquired, and supported with the traditional approach using product configuration documents.

The situation outlined by the last item will not likely change significantly because of its similarity to past practices. However, the situations outlined by the first two items will likely be more prevalent under acquisition reform. Moreover, these two situations constitute the major focus of the policy and practice changes presented in the three new configuration management documents listed previously. We highlight the aspects of these documents relevant to this discussion in the following subsections.

1. Overview of Configuration Management

> Configuration management is applied to defense material, whether hardware or software, that are [sic] designated as "systems" and "configuration items." Systems generally refer to the level at which major defense acquisitions are defined and managed. The designation of an item as a configuration item (CI) identifies the item as being a significant part of a system, or an individual item, at an appropriate level for documentation of its performance attributes and for management of changes to those attributes. The concept of CIs has confused some people into thinking that the level at which they are designated is the point at which configuration management stops. In reality, the CI level is where configuration management really begins; the process encompasses, to some degree, every item of hardware and software down to the lowest bolt, nut, and screw and software unit. This does not mean that the acquiring activity, the prime contractor, or even subcontractors have visibility or configuration control authority over every part. Rather it means that someone within the supply chain has configuration documentation and change control responsibility for each part [CM HDBK 97].

2. Current Document Change Authority

   The concept of Current Document Change Authority, introduced in MIL-STD-2549, defines the condition whereby each configuration document has a current change authority that is responsible for the content of the document and is the only authority that can make changes. This authority over the product and the documentation for the product can be transferred from organization to organization. The authority may apply at a performance level (e.g., Functional Configuration Documentation or Allocated Configuration Documentation), or at a detailed design level (e.g., Product Configuration Documentation); and may be assigned to the government, prime contractor, or at any subsequent sub-contractor level. [IDA study team interpretation]

3. Top-Level Performance Attributes

   Each government agency acquiring items (and typically true of any enterprise acquiring items) has the ultimate responsibility for the performance of the system or equipment at the top level because the agency defines in contractual terms what it wishes to acquire. However, the degree of government authority for controlling the product and documentation below the top performance level depends on such factors as type of acquisition, contractual requirements, and ownership of the data. [IDA study team interpretation]

4. Assignment of Control

   To reduce the cost of weapon system acquisition, relieve the cost premium on contractors for doing Government business, facilitate a common commercial/Government industrial base, and solve the problems relating to equipment obsolescence, Government acquisition practices were revised to adopt industry practices and to include acquisition based primarily on performance specifications. In a performance-based acquisition, the Government controls only the specified performance of the item, leaving the design solution and its implementation to the contractor. Only where absolutely necessary will the Government assume configuration control of the product baseline. In addition there will be no military standard configuration management that a contractor must comply with. The industry standard for configuration management, EIA/IS-649 is a guidance document which cites configuration management principles and best practices, and MIL-STD-2549 only provides information transactions [CM HDBK 97].

A.3.7.2 IDA Assessment

In theory, the influence of recent configuration control and management changes on competitive procurement using a TDP should not be significantly different than previously experienced—provided the following requirements are met:

- A good configuration management process is implemented.
- The process is properly followed by all involved parties.
- The status is well tracked by an effective configuration management automated information system.

However, additional risks may exist under acquisition reform that were not as prevalent nor likely to occur prior to the present emphasis on performance-based acquisition strategies. The potential for increased risk will be addressed in terms of the three competitive procurement barriers.

A.3.7.2.1 IDA Assessment – Legal Barriers

Any potential risk will be a test of how well the in-place configuration management process tracks, verifies, records, and accurately presents the state of product configuration. An example was documented by Forzono in his white paper for San Antonio Air Logistics Center:

> Every time we buy an item with the use of a performance specification, the item could come from a different source using a totally different design. Although the item would meet the performance specification requirements, the design and its piece parts would probably be different for each new item as well as supporting items [Forzono 1997].

The configuration management process will need to accommodate potential problems associated with proliferation of end items and the many unique spare parts needed to maintain these items.

Possible legal issues do not directly stem from the configuration management process but rather arise from this potential situation: that new TDPs developed as a result of these conditions could include limited rights data. Further compounding this situation is the additional workload, the result of product item proliferation, may tax the configuration management process. However, we believe the effects will be situation dependent, and likely will be only slightly negative when present.

A.3.7.2.2 IDA Assessment – Economic Barriers

Any limitations that exist today will likely exist in the future. The costs of permitting multiple configurations tend to be difficult to assess as they are influenced by a variety of factors:

- Stock, control, and distribution practices.
- Maintenance procedures.
- Manuals and support equipment.
- Personnel training.
- Future competition.

A.3.7.2.3 IDA Assessment – Technical Barriers

Inadequacy of the TDPs. Configuration management changes should not alter the potential for competitive procurement. However, when these changes occur along with performance-based acquisition, the results may be moderately negative, depending on a variety of situations. The following is a list of highlights where potential problems are most likely occur.

Know-how and process details not captured. This would not add to existing difficulties—know-how and process details are not typically captured in performance-based acquisitions.

Latent and checking and verification errors. The potential risks associated with (1) finding latent/checking and verification errors and (2) rolling back corrective actions into the documentation will likely grow if proliferation of designs and products occurs. Coordinating and incorporating fixes when multiple levels of design hierarchy are involved and when multiple part configurations exist at these levels can pose an excessive burden on a configuration management process (both the old as well as the new process).

Lagging configuration changes. Risks associated with tracking of changes, change status accuracy, and change status currency will likely rise under performance-based acquisition. Potential sources of difficulty and increased tracking/status workload include multiple-version tracking; coordination between several contractors possessing design and document control authority for multiple product configurations; existence of multiple levels of performance specifications; and design performance certification, i.e., Functional Configuration Audit and Physical Configuration Audit processes for multiple-product configurations.

Incomplete design disclosure. Incomplete design disclosure for assembly-level items acquired to performance specifications likely will not pose any new concerns, provided the assembly is a throwaway or is repaired by a contractor. However, if the item is repaired organically (depot or field), the incomplete design disclosure permitted under performance-based acquisition strategies may increase the risks of obtaining either design specifications or performance specifications for lower tier repair parts. A consequence of this type of situation may be reduced competition for parts at lower levels of assembly.

Inclusion of proprietary data or markings. Proprietary data and markings may also be present in performance specifications for lower-tier parts of assemblies acquired to performance specifications or acquired as COTS products or NDIs. This potential risk may grow under wide use of the performance-based acquisition strategy, and adversely affect competitive procurement opportunities.

Limited experience preparing reprocurement TDPs. New configuration management processes likely would not add to existing risk.

Ineffective Transmission of Procurement Technical Requirements

Contractor capabilities not matched to TDP requirements. New configuration management processes likely would not add to existing risk.

Potential of underbids and buy-ins. To the extent performance-based acquisition strategies contribute to configuration management difficulties, any resulting configuration management problems could be used as excuses for justifying "out-of-scope efforts" and increasing contract costs.

Need for a diversified pool of engineering talent. The full gamut of issues and problems that exist today likely will exist in the future, independent of the configuration management process used.

Conditions of use not as initially intended. The full gamut of issues and problems that exist today likely will exist in the future, independent of the configuration management process used.

A.3.8 Spare Parts Breakout

A.3.8.1 Summary

The objective of the Spare Parts Breakout Program is documented in Appendix E of the Department of Defense Federal Acquisition Regulation Supplement (DFARS).

> The objective of the DOD Spare Parts Breakout Program is to reduce costs through the use of competitive procurement methods, or the purchase of parts directly from the actual manufacturer rather than the prime contractor, while maintaining the integrity of the systems and equipment in which the parts are to be used [DFARS 96].

The breakout process applies to parts that will be used as spare or repair items for a DoD system, and are likely to be acquired annually over a system's lifecycle. Breakout is a multi-step process that screens the TDPs to determine the adequacy of the TDP and the government's right to use the data for acquisition purposes. As a direct result of this data screening, acquisition method codes (AMC) and acquisition method suffix codes (AMSC) are assigned to each part.

The purpose of AMC/AMSC assignments is to provide the best possible technical assessment of how a part can be acquired. The technical assessments address factors such as the following:

> [T]he availability of adequate technical data, the Government's rights to use the data, technical restrictions placed on the hardware (critically, reliability, special testing, master tooling, source approval, etc.) and the cost to breakout vice projected savings [DFARS 96].

The AMC is a single numeric code, assigned by a DoD organization during screening, that describes for the contracting officer the results of the screening and the part's suitability for breakout. The following descriptions of the AMC are from the DFARS:

- AMC 0. The part was not assigned AMC 1 through 5 when it entered the inventory, nor has it ever completed screening.
- AMC 1. Suitable for competitive acquisition for the second or subsequent time.
- AMC 2. Suitable for competitive acquisition for the first time.
- AMC 3. Acquire, for the second or subsequent time, directly from the actual manufacturer.
- AMC 4. Acquire, for the first time, directly from the actual manufacturer.
- AMC 5. Acquire directly from a sole source contractor which is not the actual manufacturer.

The AMSC is a single-digit alpha code, assigned by a DoD organization during screening, that provides additional engineering, manufacturing, and technical information, and serves as further guidance on the suitability of the TDP for competitive acquisition. A listing of abbreviated definitions of the AMSC follows.

AMSC A. Government's right to use data is questionable.

AMSC B. Part must be acquired from source(s) specified on drawing — suitable data, data rights, or manufacturing knowledge not available.

AMSC C. Part requires engineering source approval by design control activity in order to maintain quality-unique design capability, engineering skills, and manufacturing knowledge needed and must be demonstrated.

AMSC D. Data needed to procure part competitively is not available, can not be obtained economically, nor is it possible to draft adequate specification for competition.

AMSC G. Government has data rights; and no technical data, engineering, tooling, or manufacturing restrictions (candidate for full & open competition).

AMSC H. Government does not have possession of sufficient, accurate, or legible data to purchase from other than current source(s) for immediate buy and only while data under review for deficiency resolution and rescreening.

AMSC K. Part must be produced from approved class 1 casting or similar type forgings.

AMSC L. Annual buy value below screening threshold established by activity.

AMSC M. Manufacture requires use of master or coordinated tooling.

AMSC N. Manufacture requires use of special test and/or inspection facilities to determine and maintain ultra-precision quality.

AMSC O. Part was not assigned code when it entered inventory, screening not completed.

AMSC P. Government has data but not the rights to use — uneconomical to reverse engineer.

AMSC Q. Government does not have data and/or rights to data; however, future breakout is expected - data to be delivered, acquired, etc.

AMSC R. Uneconomical to buy data, rights, or reverse engineer — used when Government did not initially purchase data or rights.

AMSC S. Acquisition restricted to Government approved source(s) because of military sensitive technology.

AMSC T. Competition limited to source(s) which are listed on qualified products list (QPL).

AMSC U. Cost to breakout exceeds projected savings of competition.

AMSC V. Designated high reliability part — data needed to control can not be obtained nor is it possible to develop adequate specifications for the purpose.

AMSC Y. Design of part is unstable.

AMSC Z. Part is commercial/non-developmental/off-the-shelf item.

AMSC E, F, I, J, W, and X. (Reserved or Not Authorized)

As may be determined from these codes, data are screened for the government's right to use the data and for physical completeness (e.g., essential dimensions, tolerances, processes, finishes, material specifications); and are technically reviewed for the adequacy of TDPs to produce a part of the required performance, compatibility, quality, and reliability. As a part of the process, the cognizant reviewing DoD agency must assess the economical benefits of eliminating limitations to competition and spare parts breakout.

A.3.8.2 IDA Assessment

Defense spare parts acquisition practices received a black-eye in the early 1980s as the result of adverse publicity from the procurement of spare parts at excessive prices. A major DoD attempt to correct pricing problems and to reduce the potential cost of future spare parts involved increasing the emphasis on competitive procurement. One action was to increase the priority and status reporting of the Spare Parts Breakout Program.

The direct effect of the Spare Parts Breakout Program on competitive procurement of spare parts using TDPs will not change significantly in the future. Given that this program will have little direct influence on the issue at hand, we are taking a slightly different approach for this assessment area. No attempt is made here to assess the effectiveness of this program, nor do we assess the effects of other initiatives that may have helped to increase the competitive procurement of spare parts (e.g., establishment of competition advocate offices throughout the Office of the Secretary of Defense and the Services, the Defense Procurement Improvement Act, and the Competition in Contracting Act). Instead, our assessment uses the Spare Parts Breakout Program as a means to characterize what constitutes an adequate TDP, and to provide some comparison measures of how frequently the TDP is considered adequate.

We focus on items that the Warner Robin Air Force Logistics Center (WRALC) manages—therefore, our assessment may not necessarily reflect trends elsewhere in the Air Force, Navy, Army, and Defense Logistics Agency. We did not attempt to collect additional information to see if the trends observed at WRALC would be different elsewhere.

For our analysis, we used data from the Spare Parts Breakout Program screening process performed at WRALC during the period of January 1, 1991, through June 21, 1997. A total of 13,122 technical data packages were screened and assigned the appropriate AMC and AMSC codes by WRALC personnel in this period. AMSCs were combined into sev-

eral convenient categories as depicted in Table A-1. This table provides a summary of the screening results where AMC 1 and AMC 2 were combined as a single category called "Competition," and AMC 3 and AMC 4 were combined as a single category called "Actual Manufacturers."

Table A-1. Results of Spare Parts Breakout Screening at WRALC[2]

Categories	AMSC	Competition	Actual Manufacturers	Total
LIMITED DATA RIGHTS ISSUES. Government may have a limited rights problem for some of the data in the TDP.	A, B, P, Q, R	5.51%	30.84%	36.35%
KNOW-HOW & EQUIPMENT LIMITATIONS. Data possessed by government may not include necessary engineering or process knowledge, or special tooling, equipment, or facilities.	C, K, M, N	1.39%	1.54%	2.93%[a]
SOURCE RESTRICTIONS. Acquisition limited to government-approved sources or sources on qualified products lists.	S, T	0.43%	0.18%	0.61%
DATA NOT AVAILABLE. Government does not have needed data available to procure competitively because accuracy issues exist; data too costly to obtain; data needed to control processes cannot be obtained; or the part design is unstable.	D, H, R, V	0.59%	7.31%	7.90%[b]
ECONOMIC ISSUES. The cost to breakout exceeds projected savings of competition.	U	0.56%	2.04%	2.60%
COTS/NDIs. Items are commercial, NDI, or off-the-shelf.	Z	1.27%	4.46%	5.72%
FULL AND OPEN COMPETITION. Government has data rights and no technical data, engineering, tooling, or manufacturing restrictions.	G	43.85%	0.00%	43.85%
REMAINING ISSUES.		0.00%	0.00%	0.03%[c]
TOTALS		53.59%	46.36%	100.00%

a. Includes one item from AMC 5 (acquired as pass-through from the prime contractor) that was not in the competition and actual manufacturer's data categories.

b. Includes one item from AMC 5 (acquired as pass-through from the prime contractor) that was not in the competition and actual manufacturer's data categories.

c. Includes four items that were not in the competition and actual manufacturer's data categories: three from AMC 0 (screening not complete), and one from AMC/AMSC 2L (first-time competition and annual buy value below screening threshold).

The data reflected in Table A-1 reports on all screening accomplished under the Spare Parts Breakout Programs at WRALC for the period specified, and reflects double count-

2 Screening occurred between January 1, 1991, through June 21, 1997.

ing when a TDP for an item is re-screened. It is conceivable that the double counting could give a false indication of the trend. However, data in the next table, Table A-2, tend to discount this as a potential. This table shows the general trend reported in Table A-1 to be very stable and representative of the competitive opportunities using the TDPs at WRALC.

Table A-2. Summary of Items Coded as Competitive During Spare Parts Breakout Screening at WRALC

FY	Overall Competition (AMC 1&2)	Full & Open Competition (AMSC G)
92	55.6%	45.0%
93	53.0%	43.6%
94	58.6%	50.8%
95	53.3%	44.1%
96	58.0%	46.8%
97[a]	51.8%	44.3%

a. Through May 1997.

While not the focus of this study, outside political and policy pressures may have played a significant role in inducing the current high levels of competition. For example, additional data showed that one year before CICA was passed, WRALC competed approximately 22% of its spares acquisitions. In the year following the passage of CICA, WRALC competed approximately 44% of its spares acquisitions.

Our task was to look primarily at mechanical parts and assemblies, but the WRALC data were for all items (electronic/electrical or mechanical). It was not practical to isolate how many of these items in these tables were mechanical-based designs.

- However, the WRALC data manager estimated that approximately 70% of the AMSC G coded items[3] were of a mechanical-design nature, and the remaining 30% were electrical/electronic.

- It was further pointed out by the WRALC data manager that while 51.8% of the overall items acquired at WRALC were coded for competition, these competitively coded items by estimated annual dollar value represented 59.3% of acquisitions.

- In comparison, the competitive coded items by dollar value for electronic warfare (EW) items and avionics items were 38.6% and 32.6%, respectively.

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[3] AMSC G: Government has data rights; and no technical data, engineering, tooling, or manufacturing restrictions (candidate for full & open competition).

- Therefore, in rough terms of the percentage by dollar value, somewhere between 60% and 70% of the non-EW and non-avionics items were assigned codes for competitive procurement.

- Hence, the preponderance of items coded for competitive procurement at WRALC were not EW nor avionics but were mechanical-design based items. A possible implication of this condition was that TDPs for mechanical products may have less barriers to competitive procurement than those used for electronic/electrical items.

The following sections address the legal, economic, and technical barriers to competitive procurement using TDPs, based on our analysis of the WRALC data.

A.3.8.2.1 IDA Assessment – Legal Barriers

The most significant barrier to using TDPs in competitive procurement was the presence of limited rights in data. The primary impediment for acquiring spare parts through competition at WRALC over the past six and a half years has been limited data rights on 30.84% of all TDPs reviewed. Alternatively, if examined solely from the perspective of items coded for acquisition from the actual manufacturer, this percentage will more than double to 66.52%.

Looking at items coded for competition in this same set of data, an additional 5.51% of all TDPs were restricted from full and open competition because of data rights issues, yet some level of competition was still assessed as possible. This latter situation exists when multiple contractors have legal access to data with limited rights (e.g., prime and actual manufacturer; sources developed by the prime). While not a specific focus of this analysis, future mergers and acquisitions involving sources of items falling in this category could force some change from the Competition category to Actual Manufacturer category in Table A-1.

We found it unlikely that the effects of new acquisition reform initiatives, policies, and practices have found their way into these data. The fact that WRALC manages a very low number of spare parts for AMRAAM (Advanced Medium Range Air To Air Missile), a relatively new missile system, is an indication that the effects of the newest acquisition reform initiatives will not find their way into the spare parts breakout screening data for several years.

Only 81 items dedicated to the Air Force's AMRAAM missile program have undergone the Spare Parts Breakout Program screening by WRALC. Based on visual inspection of the 81 names, most of the items are associated with test rounds, support equipment, and test equipment. Because these missiles do not have a current organic (in-house defense) repair depot, they are sent back to the prime contractors for repair. As a consequence, the spare and repair parts used by the contractors are not being acquired by the government directly and are not subject to the Spare Parts Breakout Program screening.

Discussions with logistics personnel in the Services and Defense Logistics Agency, program office personnel, and defense contractors all indicate that the situation found with AMRAAM will tend to be the rule when contractors are responsible for repair of assemblies. When this situation exists, decisions for spare parts competitive procurement, sole-source procurement, or in-house manufacturer rest with the contractor responsible for the repair action. Furthermore, the need for contracting out assembly repair will likely increase under performance-based acquisition where the contractor retains configuration control and design ownership. The full effects of these changes on competition are not known; however, it is likely that contractors with configuration control and design ownership will control the degree of future competitive procurement for subassemblies and spare parts.

A.3.8.2.2 IDA Assessment – Economic Barriers

The data from WRALC indicate the cost to break out a spare-part acquisition from an actual manufacturer exceeded the projected savings of competition for about 2% of all TDPs screened. This relatively low percentage indicates that the costs associated with obtaining data, correcting data errors, eliminating source restrictions, and generally pursuing other actions that promote the transition to competitive procurement of spare and repair parts are generally justified on an economic basis. But we should note that this same data show that limited data rights issues persist (over 30% of the time).

A new cost category may need to be considered in the future as the effects of performance-based acquisition strategies move down the functional responsibility pipeline from development and initial acquisition to the logistics community. Potential new data-availability challenges may exist that tend to add costs:

- Lower-level performance-based specifications may not have been developed for spare and repair items when a primary assembly was acquired to performance-based specifications.

- Lower-level performance-based specifications may be proprietary to the original manufacturer for spare and repair items when a primary assembly was acquired to performance-based specifications.

- Lower-level detailed designs and drawings may be proprietary to the original manufacturer for spare and repair items when a primary assembly was acquired to performance-based specifications.

The associated costs of obtaining any additional data falling in this category, as well as their relative savings benefits, are difficult to assess at this time. All Service and DLA personnel interviewed expressed concerns that performance-based acquisition strategies would have a tendency to increase the relative incidences in which limited rights in data for spare parts were an issue, or would increase the costs associated with developing performance specifications at lower levels of assembly for spare parts.

As of this writing, we did not find any past studies or costing models concerning assessment of the relative benefits and cost-avoidance alternatives between *initial system development and production* versus *system lifecycle support, modification, and repair.* The economic effects of performance-based strategies and long-term spares costs will not likely lend themselves to reliable and reasonable analysis for the foreseeable future (for at least 5 to 10 years because of the extended time required for changes to be reflected in actual spares acquisitions of yet to be fielded systems, and the time needed to collect data once spares are acquired).

A.3.8.2.3 IDA Assessment – Technical Barriers

Inadequacy of the TDPs

Data from WRALC indicate that for cases where data rights were not an issue, two principal reasons were used to justify procurements of spare parts from the actual manufacturer based on technical inadequacy of TDPs:

- Data not available – 7.3%.
- Process and design know-how lacking, or specialized equipment and facilities not available – 1.5%.

These percentages may have a tendency to increase for the same reasons cited under Sections A.3.8.2.2 on page A–45. No other technical adequacy issues are evident from the WRALC data. But this is not to say that the presence of configuration management problems and proliferation of spare part configurations because of performance-based acquisition strategies would not manifest themselves as yet even greater increases in these two percentages.

Ineffective Transmission of Procurement Technical Requirement

Data from WRALC's Spare Parts Breakout Program do not provide any insight concerning the potential effectiveness of exchanging data between the government and competing contractors.

Appendix B.
F/A-18E/F
Electronic Data Accession Library Concept

B.1 Overview

Engineering technical data for the F/A-18E/F aircraft will be retained in an Electronic Data Accession Library (eDAL) being established by Boeing. Originally, eDAL stood for Electronic Data Accession List and was developed under the Engineering and Manufacturing Development (EMD) phase of the F/A-18 E/F Program by Boeing. The objective behind the eDAL concept is threefold:

- To significantly enhance processes to electronically browse, access, and obtain product definition data.
- To permit access of data from a single centralized location.
- To interface Web-based multi-application and multi-platform operations.

At the outset of the F/A-18E/F program, the Navy told Boeing that it wanted access to all government-owned data but not the ownership of the database infrastructure itself. Initially, the data accessing list was paper based, evolving into the current electronically accessible database. As of this writing, the Boeing eDAL concept incorporates a "firewall" or gateway port for access by Navy users and a Contractor Integrated Technical Information Service (CITIS).

The following sections provide more details about the F/A-18E/F eDAL, a discussion of ground rules governing data that reside in eDAL, and a discussion of expanded capabilities and future growth of CITIS and eDAL.

B.2 Description of eDAL

The F/A-18E/F contract requires that the contractor establish a database for technical data and provide the Navy with data access as required. The contract did not specify data formats nor the method by which the contractor should retain technical data; these details were left up to the contractor. Boeing[1] based its eDAL application on Enterworks.Com's[2] Virtual Database Software Suite which is installed on Boeing's CITIS.

eDAL provides on-line electronic access to product definition data through the various nodes as depicted in Figure B-1 on the next page. Navy organizations may access the online data with a Netscape browser. This browser provides password access through the firewall into the Boeing CITIS and then to the eDAL. Real-time access is also provided to Boeing's F/A-18E/F product definition data in the eDAL database. In turn, the eDAL tools may access eDAL database nodes at Northrop Grumman.

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[1] Then McDonnell Douglas

[2] A subsidiary of Telos Corporation.

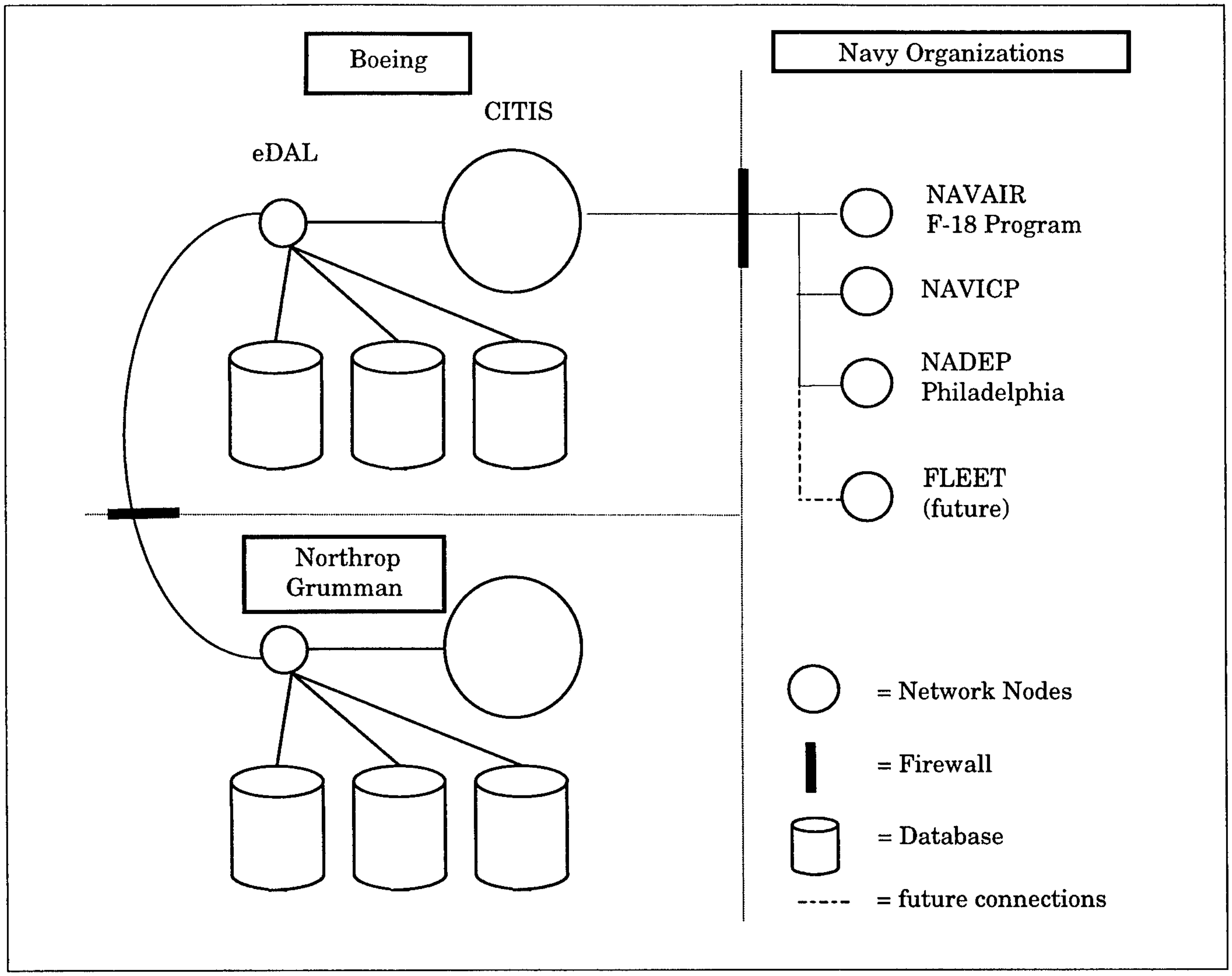

Figure B-1. Illustration of the CITIS and eDAL Concept in Use on the F/A-18E/F

eDAL acts like a broker that provides access services when requested data are not online at Boeing or Northrop Grumman, or reside at a one of the subcontractors.

- A request must be processed to the organization holding the data, the data must be put in electronic form if not already in a compatible format (i.e., scanned drawings or convert electronic data to a common user format), and then the data is read into a temporary online eDAL database or "vault."
- Current plans set a goal of three days in putting the requested data in the temporary database. This data will be automatically retained for 90 days and then deleted unless special arrangements are made.
- If data are needed again, this process may be repeated.

- The apparent duplication of deleting and re-accessing data for the temporary database assures the user that the most current data and configuration are available. If this process was not used, a more costly data configuration control, management, and update process would be needed to assure the desired data quality and accuracy. This process also assures that the vault will not be overburdened with useless data.

Boeing conducted an early paper-based evaluation of the data accession list concept (called DAL) to verify its capability of preparing technical data packages (TDPs). Four subsystems/assembles were selected for the demonstration: one from Kaiser, two from Hamilton Standard, and one from Northrop Grumman. The Navy did not note any documented errors or inconsistencies with the submitted TDPs. The Boeing and Navy personnel interviewed generally agreed that eDAL will exceed the performance capabilities demonstrated in the paper-based demonstration.

Intentionally excluded from the eDAL database are classified and proprietary data. If the Navy needs data of this nature, requests are to be processed separately and any funding or special handling requirements will be addressed on a case-by-case basis.

Typical outputs of the interactive data retrieval and display include bill of materials, three-dimensional geometry data, two-dimensional drawing data, quality plans, process specifications, material specifications, and planning reference files. The current eDAL browse capability supports composite parts, sheet metal parts, machine numerical control parts, and structural assembly build to packages. An ongoing process is in place to add F/A-18E/F product definition data to the eDAL database; the ground rules for this process are addressed in the next section.

B.3 Data Ground Rules

Program personnel interviewed observed the key to eDAL success is the rational approach used to differentiate between *product definition data* (specifications, drawings, quality assurance plans, etc.) and *process definition data.* Boeing and the F/A-18E/F Program Office have developed a set of very prescriptive ground rules used to determine what data will be incorporated in the eDAL database. The ground rules are dynamic and represent a living document subject to mutual redefinition on a continuing basis.

Because of the significance of the ground rules to the fielding of a successful eDAL process, we are providing the reader with the complete list from the *Contractor/Navy F/A-18E/F eDAL Team Ground Rules* [Navy 1997]. Not all of the ground rules may be of interest to all readers, but we decided to include them all to illustrate their full scope.

1. The eDAL provides electronic access to new/modified F/A-18E/F Air Vehicle prepared technical data. F/A-18E/F Support Equipment, Trainer and Ancillary Equipment technical data will be included in the eDAL application after formal contractual authority has been received. Retrofit, Spares, Test Articles and other non-production hardware are not included.

2. The mutually agreeable eDAL checklist shall be used to identify eDAL accessible technical data. Technical data available via eDAL shall include selected "Product Definition" or "Process Definition." In general, Product Definition describes "what" product must be built (e.g., three-dimensional geometry, electronic geometry), whereas Process Definition description describes "how" to build the product (e.g., step-by-step Work Instructions). Process Definition data is dependent upon the resources available to the original manufacturer (e.g., tooling, numerical control machine, etc.), thus may have limited value to a subsequent manufacturer. The eDAL Supplier Checklist shall identify the available supplier data elements. The Navy's request will identify the part number, manufacturer CAGE [Commercial and Government Entity] code and desired data element(s).
3. The eDAL includes product and process definition data applicable to new/modified F/A-18E/F Contractor Furnished Equipment and does not include or require Government Furnished Equipment (GFE).
4. Only the latest revision or version of the product and process definition data are required. Therefore, initial drafts, preliminary release or other non-final versions are not required. The exception is data provided via the eDAL vault, which reflects the version at the time the data was placed in the vault.
5. Financial, Management and Administrative data are not included or required. Financial, Management and Administrative data are considered to be non-technical, non-product related and in some cases company sensitive.
6. Proprietary and Classified data shall not be accessed electronically via eDAL. Proprietary data may be viewed at the contractors/supplier's facility with prior coordination with Boeing. Requested proprietary data shall require additional funding and will be proposed separately.
7. eDAL shall not include data in the public domain. The USN shall be responsible for obtaining public domain data including government or industry specifications and standards.
8. By the end of LRIP3, only forty first-tier suppliers end items are required to be part of the eDAL. The selected forty supplier end-items shall be mutually agreed upon by USN/Boeing during EMD [Engineering and Manufacturing Development], LRIP1 [Low Rate Initial Production], LRIP2, LRIP3.
9. First-tier suppliers end article technical data shall be pursued upon request. Therefore, first-tier supplier technical data shall be priced as an option and will only be imposed when requested by NAVAIR [Naval Air Systems Command].
10. The expiration data for the ordering of data listed on the DAL exploded list is defined by DFAR Clause 252.227-7027, Deferred Ordering of Technical Data of Computer Software.
11. All vault requests shall emanate from a single point of contact (AIR-3.3.2.1).
12. Upon mutual USN/Boeing agreement, supplier data shall be added to the 90-day eDAL vault so the USN may download the data file(s). Viewing (browse) capability of the supplier data via eDAL shall not be required.
13. The USN shall accept contractor/supplier electronic format. USN is responsible for converting to an electronic standard (if necessary) or obtaining the application software to access the data. Requested reformatting will require additional funding and will be proposed separately.

14. As a priority, Boeing/NGC [Northup Grumman Corporation] shall pursue adding "product definition" data over "process definition" data.
15. As a priority, Boeing/NGC shall pursue adding suppliers with electronic capability over those suppliers without electronic capability.
16. For EMD and LRIP1, Boeing and NAVAIR will implement a system by which NAVAIR requests and resources expended are maintained against the program target for overall eDAL activity.
17. USN sites equipment will be compatible with BOEING hardware/software. USN is responsible to equip sites with compatible hardware/software.
18. Three USN sites are granted access (NAVAIR, NAVICP [Naval Inventory Control Point], NADEP [Naval Aviation Depot] – Philadelphia). Addition of subsequent USN sites will affect scope and budget.
19. USN sites may access the eDAL during normal business hours (e.g., 0700 – 1630 Central Time Monday thru Friday).
20. The expected number of USN eDAL users is approximately 70 to 75 through 1997.
21. CALS/CITIS requirements are not applicable to eDAL. However, the eDAL is adaptable to the CALS/CITIS environment.

B.4 Extension and Expansion of Capabilities

With the initial success of eDAL/CITIS, Boeing has expanded data storage and retrieval support to other similar programs under JCITIS (Joint Contractor Integrated Technical Information System). The suite of weapon system programs included in JCITIS includes the F/A-18, T-45, F-15, and the Apache Longbow.

The Navy also anticipates data accession requirements for foreign military sales (FMS) customers of the F/A-18 aircraft. At present, the Navy and Boeing are investigating opportunities to make use of existing capabilities to meet these future needs. With the proper implementation of password and data security provisions, Boeing envisions future extensions of the eDAL/JCITIC to support the Navy's F/A-18C/D aircraft and FMS requirements.

Finally, the F/A-18E/F program is investigating opportunities to make the eDAL data more accessible to actual users in the course of maintenance and repair operations if needed. This activity is being pursued under the Integrated Data Environment (IDE) concept which includes the vision of electronically linking Navy depots, Avionics Intermediate Maintenance Depots, and Squadrons. While the goals of the IDE concept represent visions of future capabilities, we note that many of the eDAL capabilities discussed in this appendix were only a vision just a few years ago. The enabling difference has been the rapid advancement of the computer-based technologies.

Appendix C.
Verification Requirements as Part of TDPs

Technical data packages (TDPs), either delivered as a packaged set of information or as technical information that may be accessed or collected at the time of a specific need, have a variety of applications and uses by people in different disciplines. However, when used as a technical element of a contractual business arrangement between two parties (e.g., the government and an industry contractor to procure or reprocure, repair, support or redesign an item), the TDP should include the verification requirements.

The form and substance of the verification requirements may vary slightly, depending upon whether the acquisition strategy is performance based or detailed design based. When performance based, the verification requirements tend to represent the quality assurance requirements and provisions needed to verify that all necessary F3I (form, fit, function, interface) performance requirements are met for the intended use.

However, in the case of a detailed design-based acquisition strategy, some of the requirements may be embodied by the design details and are reflected in the instantiation prescribed by the drawing. For example, an item may be required to have a specific weight, plus or minus a designated tolerance, but the drawing details instead give dimensional details and tolerances for a specific material. For this example, the weight requirement may be verified by assuring (testing or inspecting) that the item's dimensions are within designated tolerances. Therefore, for detailed design-based acquisition, the verification requirements tend to represent performance requirements and corresponding test or inspections necessary to assure proper fabrication, adjustment, and assembly.

SD-15, *Defense Standardization Program: Performance Specification Guide*, provides a very good discussion on verification requirements. SD-15 points out that the government uses a variety of verification techniques to ensure that items acquired meet the specific performance or as designed requirements. It asserts that the verification technique should match the verification requirement needed for acquisition approach or strategy.

> The specification must enable the Government and the contractor to measure compliance with the specification requirements....If the user states that the item "must fit securely," the contractor needs to know how a secure fit will be verified. The acquisition manager must define in advance a finite means by which the secureness of fit will be measured. [SD 1995, p. 15]

In addition, at the end of SD-15 is a comparison of performance and detailed specification. This information is extracted and depicted in Table C-1 on the next page.

In discussing logistics requirements, SD-15 also points out that

> [t]he Government must be able to control the form, fit, function, interface(s), and interchangeability of an item in the field. Because the requirement for interoperability and interchangeability is driven by logistics support needs, each change to the performance specification must be carefully considered by the customer. Changes may have significant impact on the entire logistics environment, including spare and repair parts, training, manuals, diagnostic tools, ground support equipment, and maintenance operations. [SD1995, p. 13]

From this perspective, it is very important that TDPs include all appropriate logistics requirements (such as discussed previously) and their corresponding verification requirements to assure that essential capabilities and system performance needs will be met. If design details, manufacturing processes, materials, etc., have not changed for an item that had previously complied with the verification requirements, some or even all of the verification of logistics requirements may be accomplished by an analysis of similarity—and, as such, may not need to be formally included in the verification requirements.

However, the definition and verification of logistics requirements can represent significant workloads if design details of an item should turn out to be different, which may occur with a performance-based acquisition approach. Consequently, there may be comparatively more testing for performance in some cases, including logistics performance as noted under the "Performance Specification" column in Table C-1.

Table C-1. Comparison of Verification Requirement Differences For Performance and Detail Specifications

Specification Requirements	Performance Specification	Detail Specification
Section 4 – Verification	Must provide both the government and the contractor (manufacturer) with a means for assuring compliance with the specification requirements.	Same as for performance specifications.
1. General	Very similar for both performance and design. More emphasis on functional. Comparatively more testing for performance in some cases.	Very similar for performance and design. Additional emphasis on visual inspection for design in some cases.
2. First Article	Very similar for both performance and detail. However, often greater need for first article inspection because of greater likelihood of "innovative" approaches.	Very similar for both performance and detail. Possibly less need for first article inspection.
3. Inspection Conditions	Same for both.	
4. Qualification	Same for both.	

Source: SD-15.

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Acronyms and Abbreviations

2D	two dimension, two dimensional
3D	three dimension, three dimensional
ACD	Allocated Configuration Documentation
AIAG	Automotive Industry Action Group
AIMD	Avionics Intermediate Maintenance Depot
AIS	automated information system
AMC	acquisition method codes
AMC	Army Materiel Command
AMEC	Army Management Engineering College
AMRAAM	Advanced Medium Range Air-to-Air Missile
AMSC	acquisition method suffix codes
AP	application protocol
APML	Assistant Program Manager for Logistics
APR	Army Procurement Regulations
APT	automatically programmed tool
ASME	American Society of Mechanical Engineers
ASPR	Armed Services Procurement Regulation
BOM	bill of materials
CAD	computer-aided design
CAE	computer-aided engineering
CAGE	Commercial and Government Entity
CALS	Continuous Acquisition and Lifecycle Support
CAM	computer-aided manufacturing
CAx	computer-aided tools for design, manufacturing, engineering, etc.
CDCA	Current Document Change Authority
CDR	Commander
CI	configuration item
CICA	Competition In Contracting Act
CITIS	Contractor Integrated Technical Information Service
COTS	commercial-off-the-shelf
Ctr	Contractor
DAL	data accession list
DFARS	Department of Defense Federal Acquisition Regulation Supplement
DLA	Defense Logistics Agency
DoD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instructions
DSREDS	Digital Storage and Retrieval of Engineering Data System
DXF	Data Exchange Format
eDAL	Electronic Data Accession Library
EDCARS	Engineering Data Computer Assisted Retrieval System
EIA	Electronic Industries Association
EMD	Engineering and Manufacturing Development
EW	electronic warfare
F3I	form, fit, function, interface
FACNET	Federal Acquisition Computer Network
FAR	Federal Acquisition Regulation
FARA	Federal Acquisition Reform Act
FASA	Federal Acquisition Streamlining Act
FCA	Functional Configuration Audit
FCD	Functional Configuration Documentation

F&O	full and open
FMS	foreign military sales
FY	fiscal year
GFE	Government Furnished Equipment
IDA	Institute for Defense Analyses
IDE	Integrated Data Environment
IGES	Integrated Graphics Exchange Standard
ILS	Integrated Logistics Support
IPT	Integrated Product Team
ISO	International Organization for Standardization
JCITIS	Joint Contractor Integrated Technical Information System
JEDMICS	Joint Engineering Data Management Information and Control System
KBE	knowledge-based engineering
LRIP	Low Rate Initial Production
LTG	Lieutenant General
M/CAD	Mechanical/Computer-Assisted Design
MRP	Manufacturing Resources Planning
NADEP	Naval Aviation Depot
NAVAIR	Naval Air Systems Command
NAVICP	Naval Inventory Control Point
NAVSUP	Naval Supply Systems Command
NC	numerical-control
NDI	non-developmental item
NG	Northrop Grumman
NIST	National Institute of Standards and Technology
NSN	National Stock Number
OEM	original equipment manufacturer
P/N	part numbers
PC	personal computer
PCA	Physical Configuration Audit
PCD	Product Configuration Documentation
PDES	Product Data Exchange using Standard for Exchange of Product Model Data (STEP)
PDF	portable document format
PDL	page description language
PDM	Product Data Management
PM	program manager
PTC	Parametric Technology Corporation
RAMP	Rapid Acquisition of Manufactured Parts
RBA	Revolution in Business Affairs
RFP	Request for Proposal
S/N	Stock number
SAALC	San Antonio Air Logistics Center
SAE	Society of Automotive Engineers
SCRA	South Carolina Research Authority
SD	Defense Standardization
SM	solid modeling
SME	Society of Mechanical Engineers
STEP	Standard for Exchange of Product Model Data
TDP	technical data package
TINA	Truth In Negations Act
USN	United States Navy
WRALC	Warner Robins Air Logistics Center

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1999	Final

4. TITLE AND SUBTITLE

Adequate Technical Data for Mechanical Products in a New Defense Acquisition Era

5. FUNDING NUMBERS

DASW01-98-C-0067
Task order AH-5-490

6. AUTHOR(S)

Robert M. Rolfe, task leader, Herbert R. Brown, Brian S. Cohen, Michael B. Marks

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Institute for Defense Analyses
1801 N. Beauregard Street
Alexandria, VA 22311-1772

8. PERFORMING ORGANIZATION REPORT NUMBER

IDA Paper P-3409

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Director, Industrial Capabilities and Assessments
Rosslyn Plaza North
1777 Kent Street, Suite 1100
Arlington, VA 22209

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release, unlimited distribution: 24 July 2000	2A

13. ABSTRACT (Maximum 200 words)

IDA was tasked to develop strategies and requirements for the technical content of product data packages needed to maintain and upgrade weapon systems after the initial production phase. An IDA study team analyzed mechanical-based post-production technical data needs and practices that resulted from recent acquisition reform initiatives and advances in computer-aided technologies. Focusing on mechanical sub-systems, the team assessed how technical data content, form, and media were changing, and if the technical data for mechanical systems and parts would be adequate in the new acquisition era. Information was collected from three principal sources: literature and online data searches; defense systems acquisition, support, and logistics managers; and computer-aided design tool developers, suppliers, and users. The team's observations and discussions became the basis of its recommendation that DoD should incorporate in its reference and guidance material the mechanisms that will assist DoD programs in trading off near- and long-term technical data needs, and in identifying the best technical data lifecycle strategy to accommodate changing conditions.

14. SUBJECT TERMS

Technical data, technical data packages (TDPs), post-production, computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), lifecycle strategy, acquisition reform, acquisition policy.

15. NUMBER OF PAGES

124

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102